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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

FEBRUARY, 1933

The Scientific Work of the Government of the United States

SCIENCE GUIDES THE DEPARTMENT OF THE INTERIOR

By Secretary RAY LYMAN WILBUR
U. S. DEPARTMENT OF THE INTERIOR

OUR civilization is being made over right before our eyes under the stimulation of the forces set loose by discovery, research and invention. This new physical world has a firm basis upon undeviating universal laws. It is probably true that we have available a mere fragment of the great structure of knowledge which will eventually be brought into the service of man. Our view-points are rapidly changing. Old assumptions, theories and dogmas are being rapidly pushed out of our minds. In this period of mental ferment, shams have been exposed, the taboos of centuries released, and much has been brought up for discussion which was considered settled by our forefathers.

In the field of government there has been a rapid increase of democracy. To an increasing degree, science has become definitely associated with the development and functions of government. This is the age of democracy and science. Science has no sympathy with substitutes for the truth. Science is giving the human family a unique and unexampled service, and through it the human mind has been vastly increased in its range and mental power.

This is the day of the expert. The man who knows must be recognized and used. In the fields of science the experts can be trained and developed, but such experts require opportunity for long years of study and they need constant exposure to those who are devoting their lives to research; in fact, our progress in our modern civilization is going to depend upon the experimental method rather than upon catchwords, aphorisms or the persistent broadcasting of untried ideas. So close to-day is the link between science and its laboratories and the government that we can measure the progress of a civilization by its economic capacity to support laboratories and by the quality of the intellects brought in to them.

Previous to the depression there had been a fortunate tendency to increase the amount of work done in government laboratories which can be classified as of a fundamental character—that is to say, searching for truth for its own sake rather than for practical procedures immediately applicable to daily life. Essential research depends upon a large amount of reserve time which can be used by men of great curiosity and in-

RAY LYMAN WILBUR
SECRETARY OF THE DEPARTMENT OF THE INTERIOR

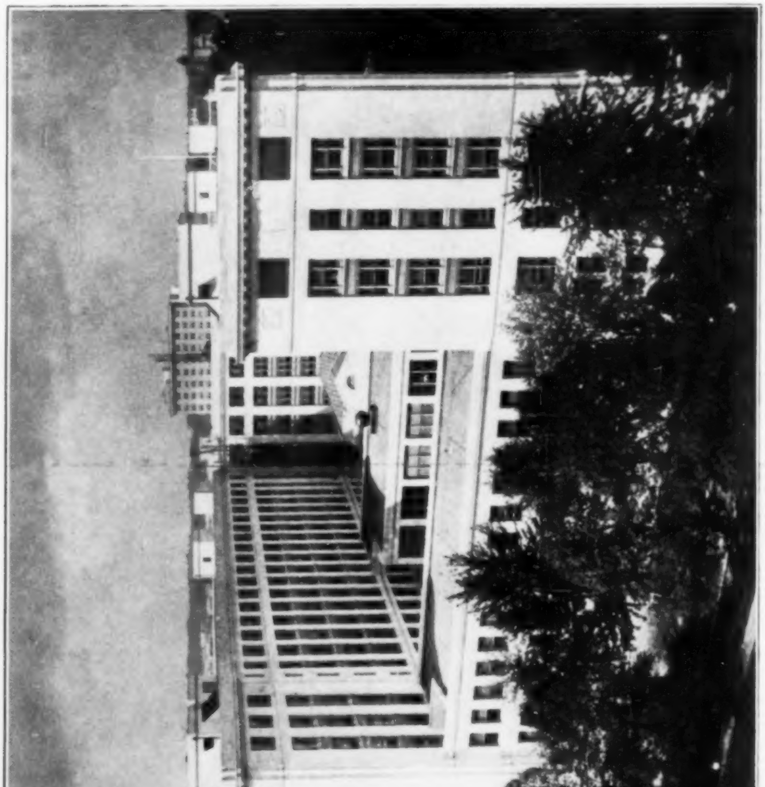
dustry without the supervision of others, except in the broadest way. The ordinary administration of government, the ordinary handling of budgets, do not lend themselves well to research. It requires its own technique. In it there will always be an apparent waste of time and false leads. Most leads into the great unknown are apt to end blindly. The discovery of new facts which, once discovered, become the eternal property of man, is full of hazards and uncertainties. In some ways the research worker has as difficult a task as that of a blind man trying to thread a needle. Many attempts must be made before success is assured. Because of this it is most important for the modern democracy to set up its relationships to science from the standpoint of the budget in such a way that funds will not be tagged for specific purposes. Funds should be made available for the securing of the best brains possibie and for the facilities that they require, in order to pursue the unknown. While this function is carried on by many independent institutions and as a part of great industrial concerns, nevertheless it seems to me that, since science and government are so closely related, government itself must make liberal grants for investigation and research. In the new world's civilization, which is now a world-wide structure, interlocked economically and with all kinds of interrelations and intercommunications, there is a new conception of world citizenship developed. Truth discovered by the citizen of any country can readily become the property of all. A democracy which is not seeking for new truth and new facts can no longer consider itself safe in this world of harsh reality, where facts determine the issue. These facts, applied either to industry or to national defense, determine not only progress but safety.

The U. S. Geological Survey is an example of the service which science can render to government. The geologist with his trained mind has made a study of that part of this great continent which is in our possession. Through years of endeavor and the work of thousands of trained men, we possess a fund of information regarding our mineral, water and soil resources which guides much of our national policy in various fields. It is obvious that without the help of the expert we would have floundered in our conquest of the natural resources of the country. Upon the imaginative mind of the geologist and his capacity to visualize the treasures stored below the surface of the earth depends much of our future national welfare. In the Geological Survey we have had much that was practical but also much that was fundamental.

As a nation we have embarked on a new period of pioneering. Our nation's frontier has dissolved in the Pacific and reappeared in the laboratory and on the school playground. Changes have been necessary to enable this department to do its part in this new pioneering, which means the wisest use of what we have instead of the conquest of new lands, new timber and new minerals. Our people are in the process of adapting themselves to a continent.

A task like that of helping the American aborigine along the path of progress, until he spans in a few generations the gap between the stone and the steel age, calls for the best of scientific thought. Medicine must wrestle with those problems of health that always confront undeveloped peoples in contact with civilization. Education must present itself to the unaccustomed mind. The psychologist must reconcile races that are ages apart. The agriculturist must bring a new training to the reservation.

Aided by all these, the Indian Service,



THE BUILDING OF THE UNITED STATES DEPARTMENT OF THE INTERIOR

has turned the corner. Its new goal is to work itself out of a job in twenty-five years. Its new methods center on splitting apart the two separate problems of the Indian's personal welfare and the protection of the Indian's property. These have necessarily been much confused during our nation's hundred years of past wading in the quagmire of Indian administration.

Administering the billion-dollar Indian estate, scattered through many states, has been a job of much clerical detail. The problems of health, education and welfare were allowed to intertwine with this clerical work. As a result, our government's treatment of Indian problems has often been from a bureaucrat's point of view. We have coddled and pauperized one of our finest racial stocks. To-day, as a result of these methods, the average Indian has neither the education, the inclination nor the ability to manage his own property.

The Federal Office of Education comes under the Department of the Interior. The education and training of our children is one of the fundamental functions of our form of government. With us this has been largely in the hands of local communities and of the states. Out of manifold experiences we are developing new points of view and new plans for the future of our American children. The potential possibilities of any child are the most intriguing and stimulating in all creation. Our children will inherit our place on this continent. We must train them to live their lives in the surroundings we have made for them. It is important for us to know how best to instruct our children from the broadest possible standpoints. The White House Conference on Child Health and Protection brought out clearly that we need to do more than to give them food, clothing, training and health protection. We must lead them to see the basic relations between them and nature and help them to follow the highest ideals and aspirations. The federal relations to the problem of education center in the Office of Education, which has also undergone important changes recently.

It was created as a research organization to gather and disseminate information on educational methods for the benefit of the states. But in the course of time it acquired many administrative functions which should have never been loaded upon it. We have relieved it of these administrative functions. Education of the Alaskan natives was transferred to the Office of Indian Affairs, and other Alaskan responsibilities given to the local government. Consequently, the Office of Education doubled its research activities. A division of special problems was created to study education of exceptional children, of native peoples, of Negroes and of children in sparsely settled regions. A new division of research and investigations was created. A third new division of major surveys was organized to supervise work under special appropriations by outside specialists. These include a nation-wide survey of land-grant colleges, a national survey of secondary education, one on the professional education of teachers, and so on.

The National Park Service does conservation work in a double sense. Wild life of decreasing species is preserved. The big trees in the scenic valleys of California, the geysers and mountains and wild life of the Yellowstone, the peaks and glaciers of Glacier National Park and the wonders of Arizona's Grand Canyon all are rendered available to our people by this bureau's work. But this kind of conservation is but a means to the real objective of the Park Service, which is the recreation and education and health of our people. We are in the midst of the rounding out

of the national park system. Three million Americans each year visit our parks. These parks are the happiest contact points between our people and their government; both gain by it. We are constantly building up its scientific staff. A corps of naturalists are always present to make the lessons of the parks available to the visitor. Geologists and archeologists have become associated with it. Museums are being built up at many points. All the time the national parks are becoming more and more a university of the out-of-doors.

The General Land Office is the agency of this government which has supervised the carving of the public domain into individual homes. Its activities have kept pace with the frontier while settlers overflowed into state after state. The usual action of the Federal Government has been to distribute land resources into private hands as fairly and rapidly as possible. Certain artificial conceptions, such as that of the acre, have been used in dividing up our continent just as we have divided up our cities into town lots of arbitrary size and shape. This has been done largely regardless of the quality of the soil, the amount of vegetation, the water supply, the climate or those other factors upon which all the values of the soil, in so far as the habitation of human beings is concerned, depend.

Unfortunately, Congress has never given the General Land Office or the states adequate authority to protect the public domain from overgrazing and abuse. About 175 million acres remain, most of it valuable principally as a source of water and for grazing. Few of our people realize the destructive effects on the water supply of our valleys which may come from overgrazing and fires in distant mountain country. When vegetation is uprooted by animals or burned by fires, the balance of forces which nature has built up through millions of years is destroyed. Rains, instead of soaking into vegetation and surface soil, run down barren slopes, wash away the surface, carry it as silt into rivers and fill reservoirs, and form disastrous floods instead of permanent streams. The growing value of the soil is lost, homes are washed away in distant valleys where the smoke of the forest fires is never seen and the grazing animals are encountered only as mutton chops and roast beef.

As to the mineral resources of the nation, this department has a large responsibility. The geologist, the mineralogist, the oil technician, found here a task worthy of his best efforts. Hidden beneath the surface of this land of ours were great stores of coal, oil, natural gas and minerals of many varieties stored there through the ages. In the more thickly settled portions of the country these rapidly came into the possession of private individuals who developed them in accordance with existing economic practices and demands. Fortunately, immense stores were so distant from the market, or so hard to master, that they were left intact, although they were subject to entry as mineral claims. Retaining these for the benefit of the people and permitting their development with a minimum of waste presents problems that only science can meet.

The Bureau of Reclamation has created over a billion dollars of wealth for the nation by its score of reclamation projects throughout the West. There science has turned deserts into prosperous empires in the Salt River Valley in Arizona, and on the Rio Grande, the Colorado, the Columbia and on lesser streams. Reclamation is a wise national policy. It is self-supporting; all construction is financed from a revolving fund which the settlers repay.

To-day we are engaged on the greatest reclamation project of all history.

the building of Hoover Dam on the Colorado River. The problems it presents run the whole gamut of science. Through sale of electric power, already contracted for fifty years, the falling waters of the Colorado will pay for their own capture. A river which is now a threat to hundreds of thousands of acres of farm lands in Arizona and California will be converted into a steady stream of about the valume of the Hudson River at Troy. It will carry commerce, water thousands of acres of arid public lands and furnish drinking water to a dozen cities.

The Territory of Alaska is big enough and rich enough to deserve the fullest possible development. Its resources will still be available for our grandchildren even if used to the utmost now.

The problem of agriculture under the climatic conditions it presents offer a new challenge to science. Its hillsides, rich in minerals, call for new forms of attack. The fish of its streams, its fur seal colony, its reindeer herds, invite science to new applications of its principles.

In Hawaii, in the mid-Pacific, the department finds contrasting tropical fields to which science may be brought. How well it has succeeded is shown by the fact that large areas to-day are producing unbelievable yields of twelve tons of sugar to the acre and twenty tons of pineapples. Hawaii also presents such a laboratory for the study of race admixtures as has never before been available to any scientific group.

Whether it be the control of trachoma among the Indians, the application of experimental methods in devising means for cooling the great mass of cement in the Hoover Dam or a test of gas pressures in an oil field, science is constantly at work in the operations of the Federal Government in so far as they are placed in the Department of the Interior.

CANYON DE CHILLY, ARIZONA.

THE UNITED STATES GEOLOGICAL SURVEY

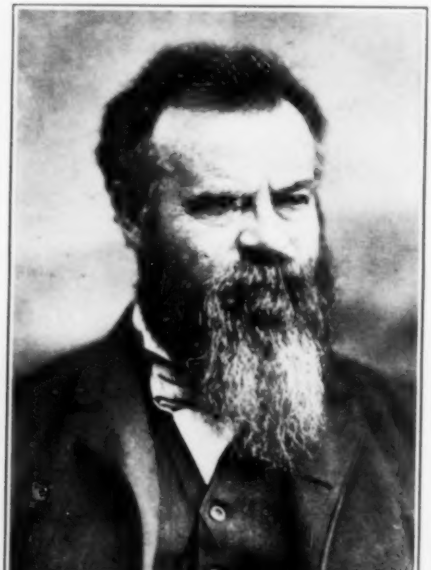
By W. C. MENDENHALL
DIRECTOR

ORIGIN

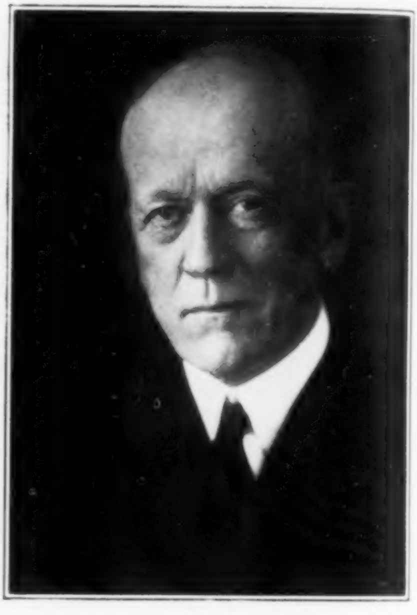
WHILE the U. S. Geological Survey was created by a congressional mandate expressed in the act of March 3, 1879, that mandate was itself a recognition of the development, through the first three quarters of the nineteenth century, of geology as a systematic culture, with widely useful applications in human affairs. Prior to the Civil War several state surveys had been organized, some ephemeral, some permanent. Hitchcock in Massachusetts, the Rogers brothers in Pennsylvania and Virginia, David Dale Owen in Indiana and the Mississippi Valley, Whitney in Michigan and later in California, Safford in Tennessee, Hall in New York, Newberry and Blake in the Southwest, are a few leading names among those associated with official surveys whose work helped to establish the principles and the applications of the science. The Civil War itself checked activities of this sort, but its end released abundant national energies, and the great West then beckoned to the geologic as well as the geographic explorer. Soon Dr. F. V. Hayden resumed his explorations of the upper Missouri Valley, which had begun as early as 1853, but which only after the war developed into the great scientific exploratory organization commonly known as the Hayden Survey. In 1867 Clarence King, who had served his apprenticeship under Whitney in California, organized the Survey of the Fortieth Parallel. In 1869 Lieutenant George M. Wheeler, of the U. S. Army engineers, began his surveys of the Southwest and Major J. W. Powell accomplished his famous exploration of the Grand Canyon, followed in later years by work in adjoining territory. Powell's work, like Hayden's, was carried out under the auspices of the Department of the Interior; the explorations of King and Wheeler were under the War Department. These four great exploratory surveys brought back striking geographic and geologic results, which attracted wide attention in this country and abroad and led to increasing public support. But the time inevitably came when it was realized that this work under separate organizations, brilliantly conducted though it was, inevitably overlapped in some measure and needed to be coordinated, so that order might be brought out of the growing confusion. Congress in 1878 called upon the National Academy of Sciences to consider the methods of conducting the existing surveys and to recommend a general system designed to obtain the best possible results at the least possible cost. The academy responded in a report approved at a meeting held in New York on November 6, 1878. This report recommended a logical and comprehensive reorganization of the existing agencies engaged in mensuration surveys and in surveys of geologic and economic resources. Its recommendations, however, were carried out only in part. So far as Congress deemed it wise or practicable to adopt them, they were embodied in the organic act of the present Geological Survey, which was established within the Department of the Interior and charged with the examination of the geologic structure, the mineral resources and products of the national domain and the classification of the public lands. The preexisting surveys were at the same time discontinued.

CLARENCE KING
DIRECTOR OF THE SURVEY, 1879–1881.

Clarence King, the brilliant head of the Fortieth Parallel Survey, who had become widely known in scientific circles through the able reports of his organization and who had attained popular renown through his exposure of the spectacular diamond fraud in southern Wyoming in 1872, was named as the first director of the new organization. King, a friend and intimate of John Hay and Henry Adams, was a man of great versatility and of rare personal charm, but administration, with the peculiar types of burdens and responsibilities that it involves, was not to his liking, so after launching the new bureau he resigned on March 11, 1881, after less than two years of service. He was succeeded by Major John W. Powell, co-scientist and co-explorer, who, like his predecessor, had prepared for his new work through experience as head of one of the four preexisting organizations.



JOHN W. POWELL
DIRECTOR OF THE SURVEY, 1881–1894.



CHAS. D. WALCOTT
DIRECTOR OF THE SURVEY, 1894–1907.

The roster of employees in the first annual report of the Geological Survey indicates clearly that the leading geologists and geographers who had participated in the earlier surveys were

GEO. OTIS SMITH
DIRECTOR OF THE SURVEY, 1907–1930.

brought into the new organization. Among the geologists appear the names of F. V. Hayden, G. K. Gilbert, S. F. Emmons, Arnold Hague, Raphael Pumpelly and G. F. Becker, and among the geographers Richard Goode, J. H. Renshawe, A. D. Wilson and Gilbert Thompson. W. F. Hillebrand, later to become one of the leading inorganic chemists of the world, was also a member of the group. The new organization was thus born full grown, so to speak, with a staff of trained men, many of them already famous.

Among the earliest questions that confronted Director King was that of the geographic extent of the Survey's field of activities. The organic act defined this field somewhat ambiguously as coextensive with the national domain. Director King construed "national domain" as essentially the region of the public lands. He recognized, however, that the new organization's value would be seriously limited if its activities were to be confined to a region which, in the nature of things, must constantly shrink, and his first annual report contains a strong plea to Congress to remove the ambiguity and consequent uncertainty as to the extent of its field of operations. This matter was not finally clarified until 1888, when areal restrictions were removed by making the appropriations of that year available for "geologic surveys in various portions of the United States." This authority has been continued since.

ORGANIZATION

The Survey staff, nearly 80 per cent. of which is technical, includes about 1,000 persons—geologists, engineers, chemists, physicists, editors, librarians, accountants, draftsmen, preparators, clerks, aids of various types, messengers, etc. Its main offices, with library, laboratories and engraving and printing plant, are in the Department of the Interior building at Washington, but it also has 60 field offices distributed over the United States and in Alaska and Hawaii.

W. C. MENDENHALL
DIRECTOR OF THE SURVEY, 1931–

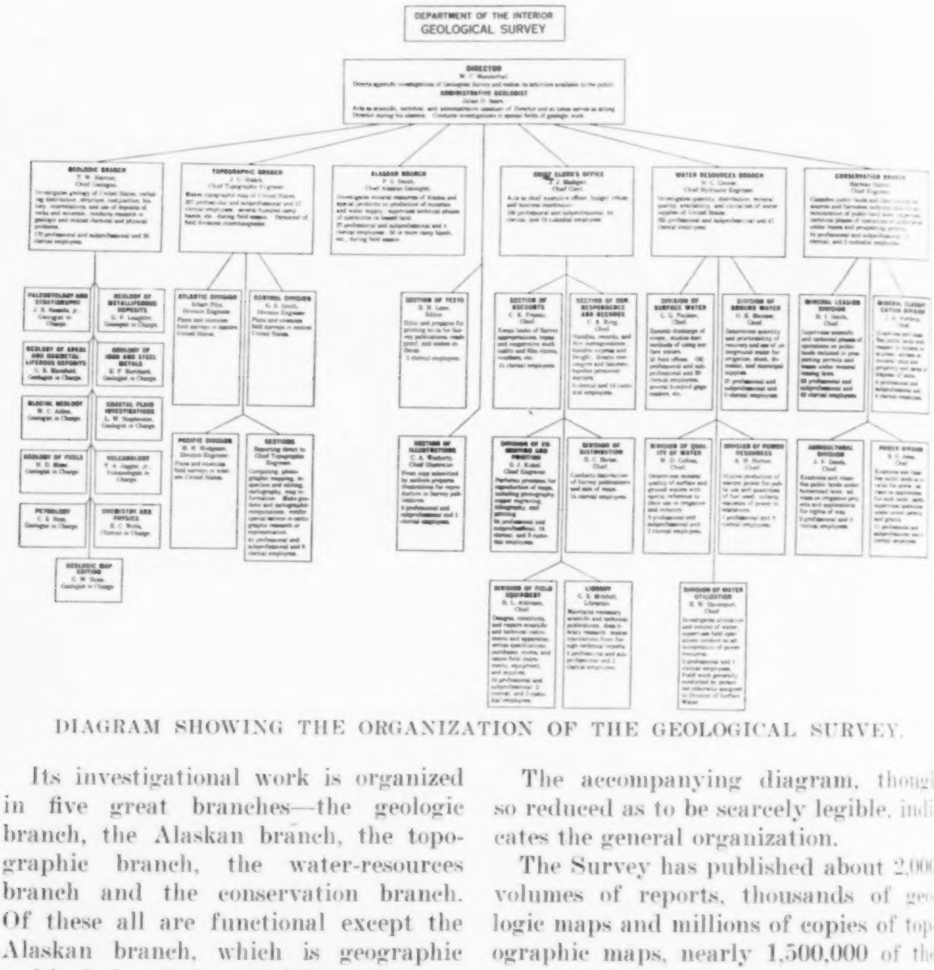


DIAGRAM SHOWING THE ORGANIZATION OF THE GEOLOGICAL SURVEY.

Its investigational work is organized in five great branches—the geologic branch, the Alaskan branch, the topographic branch, the water-resources branch and the conservation branch. Of these all are functional except the Alaskan branch, which is geographic and includes all the activities of the Survey in Alaska. Each branch contains several divisions and sections through which the work is administered in detail.

The subsidiary services—including the engraving and printing plant, in which are engraved and printed all folios and topographic maps, many geologic maps in addition to the folios and miscellaneous maps for other government establishments; the library of 200,000 or more books and pamphlets, mainly geologic; the editorial group; the accounting and distribution sections, and the instrument shop—are administered through the director's office.

The accompanying diagram, though so reduced as to be scarcely legible, indicates the general organization.

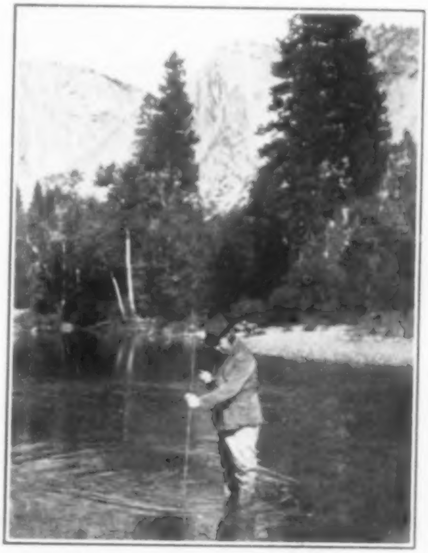
The Survey has published about 2,000 volumes of reports, thousands of geologic maps and millions of copies of topographic maps, nearly 1,500,000 of the topographic maps having come from the presses in 1932 alone.

Geologic Work

From the beginning of its history, although other functions have been given to it by law, either directly or by implication, the Survey has regarded geology as its primary field. Geology, of course, like the other general sciences, is now a complex group of fields of knowledge, not a single field, and geologic investigations are staff investigations rather than those of an individual. Moreover, geology has many interrelations with the sister sciences of physics, chemistry, as-

tronomy and biology. Paleontology in its various branches; general evolution, as it may be studied and interpreted through the remains of extinct life, vegetable or animal; sedimentation, its processes and products; mineralogy; petrography as an aid in the study of igneous and altered rocks particularly; metallic ores, the conditions of their deposition and their distribution; nonmetalliferous deposits of economic value; the evolution of the earth's crust, the structural features that affect it, the surface forms that are impressed upon it, and the agencies that have produced these forms; volcanology; chemistry and physics as they are involved in studies of rocks—all these and others fall within the fields covered by geology, and all of them have received some measure of the energies available to the Survey since its establishment. Its founders, although they inherited the experience and much of the personnel of the earlier national surveys and had access to the knowledge acquired through the activities of the preexisting state organizations, nevertheless had to establish principles to guide the conduct of the new organiza-

MEASURING THE FLOW OF A STREAM BY MEANS OF CABLE AND CAR.



GAGING A STREAM BY WADING.

tion and to adapt or evolve systematic methods by which its work could be accomplished. Simple areal mapping, one of the most valuable means of revealing critical geologic relations, itself required decisions as to scales to be used, degree of refinement of the work, definition of units, and methods of field work that would yield clear and consistent final products.

The mineral deposits, particularly of the then new West, were among the things of economic importance with which the new organization was expected to deal helpfully, from the beginning. In order that it might aid the mining industry in a practical way, intensive and thorough studies were essential, to decipher the laws governing those particular types of earth chemistry and rock alteration which result in ore deposits. The studies at Leadville and on the Comstock Lode were pioneer investigations to this end, involving cooperation by geologists, chemists and physicists. They greatly increased the understanding of the complex laws of ore deposition and association.

TOPOGRAPHIC PARTY AT WORK BELOW BOULDER RAPIDS IN MARBLE CANYON OF COLORADO RIVER.

In the field of ores of the metals intensive studies of known deposits have resulted in a better understanding of conditions of ore occurrence, which has greatly extended the productive life of the districts studied, as at Leadville. Even more important, however, is the fact that the accumulation of such data has led to broad and highly practical generalizations on ore occurrence. Such concepts are the theory of enrichment, the theory of zonal distribution of primary ore deposits, and the relation of ore deposits to apically truncated stocks. The application of these principles and others by the mining industry has resulted in greatly increasing the probabilities of success in the exploitation of metal deposits and has prevented expensive exploration of many unprofitable deposits.

At present studies that promise to be equally fruitful are being directed toward the relations between ore occurrence and the geologic structure of the surrounding region. Metamorphism, mild or intense, has practically always accompanied deposition of the metals, and further systematic study of the results of this process is likely to give significant clues to the positions and relations of ore bodies.

The prospecting of the future must be guided by geology. The old easy days, when in an undeveloped mining country the prospector, working at the surface with his pick, could uncover bonanzas, are gone. The rich deposits to be found hereafter lie not at the surface, but deeply buried, and must be discovered, if at all, by the application of geologic principles.

The ultimate value of any science lies, of course, in its applicability to human needs and human advancement. But the inherent nature of research—a systematic endeavor to learn the unknown, to extend man's knowledge of the substances and forces of nature—is such that progress in it must be slow. What mankind in the mass is mainly interested in is the application of science; what too few realize is the long period of patient labor involved in the establishment of guiding principles or the finding of new products.

A quarter of a century or more ago the Geological Survey began a systematic search for usable deposits of the fertilizer mineral potash in the United States. None of any importance in this country were then known. Slowly, as energy and funds could be made available, all promising regions within our borders were examined. The great salt deposits of New York, Ohio, Michigan and Kansas were investigated. All the Western playas were systematically studied and tested. Failure after failure resulted: one locality after another was discarded. Eventually, in part as a result of the Survey search and in part as the result of the activities of industry, two Western localities were developed—Searles Lake, in California, and the Salduro Basin, in the western part of the Great Salt Lake depression. But it was hoped that more extensive bedded deposits, similar to those of Europe, might be found, and the search continued. After other localities had been eliminated, it still seemed possible that commercial bodies of potash might exist in the great Permian salt basin that extends northeastward from western Texas and eastern New Mexico into Oklahoma and Kansas. Attention was concentrated on this basin. Studies were made of cuttings from wildcat oil wells that were being drilled here and there in the basin, and polyhalite, a low-grade potash mineral, was found in many of these cuttings. The search was intensified in the hope that richer salts might be found. Eventually drillers of a wildcat oil well in eastern New Mexico, on the alert because of Survey stimulation, found sylvite. Cores were taken, and sylvite and other rich minerals were found in beds sufficiently thick to be

VIEW OF THE AJO COPPER MINE IN ARIZONA, WHICH IS BEING STUDIED BY THE GEOLOGICAL SURVEY.

mined. There now exists, near Carlsbad, New Mexico, a successful potash mine which has already produced nearly 100,000 tons of salts running 25 per cent. or more of K_2O. Other mines are in course of development. This result is the culmination of a long series of patiently conducted studies with an economic objective.

Early in the exploration for crude petroleum, the anticlinal theory was evolved by I. C. White. Modified and developed from its original form, it has been an important instrument in the search for crude petroleum for more than half a century, and its use has tremendously simplified that search and increased the chances for success. A later and only less important generalization is David White's carbon ratio theory, which eliminates great areas in which millions of dollars might have been wastefully expended. Investigations are now being made as to the source materials of petroleum. Scientific men can not predict the outcome of their studies: if they knew the outcome, the studies would be unnecessary. Hence no claim can be made about the results that may accrue from this study, but it may easily be possible that, as the anticlinal theory aided in the concentration of the search in the more favorable areas and as the carbon ratio theory added further limitations and thus gave new guides to explorations for oil, so the studies of source rocks may furnish to those engaged in the search for new pools an additional factor of control.

Topographic Mapping

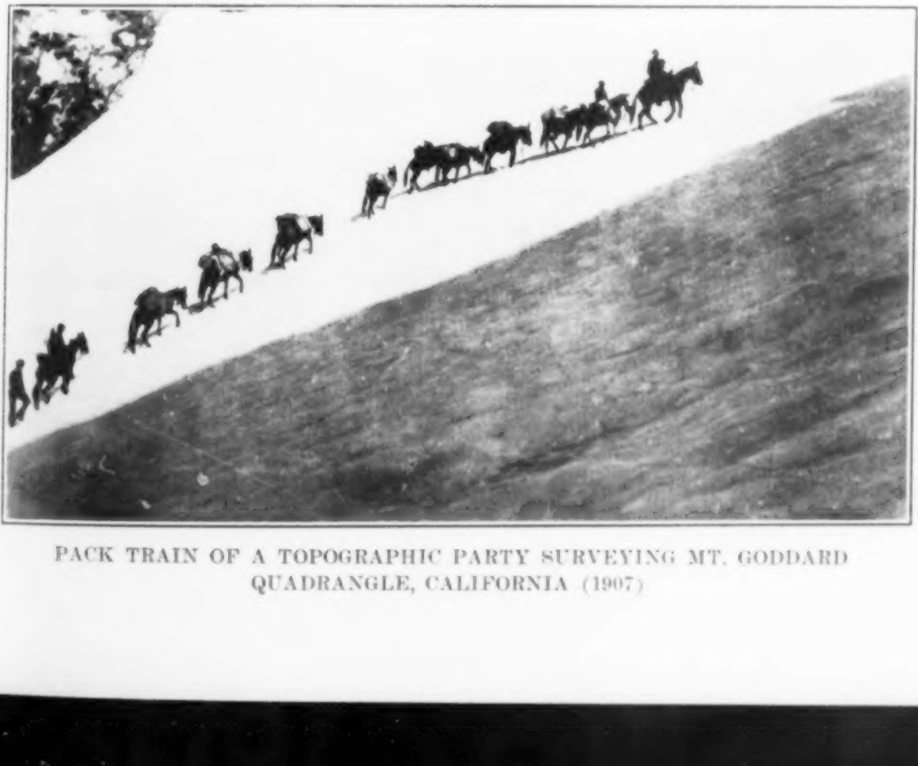
It was realized from the beginning that geologic mapping could not be accomplished without base maps on which to record geologic units in their proper relations. So the Survey has always made topographic maps. It inherited the art of map-making in its earlier and crude form from the preceding organizations, but it has developed this art until the modern topographic maps are not only rigidly controlled as to position and adapted in scale to the various uses for which they are designed, but are both accurate and graphic in their delineation of land forms in all their infinite variety. They now find manifold uses other than their original use as base maps for geologists and are in wide demand everywhere, but less than half of the United States is yet covered by these maps.

Water Resources

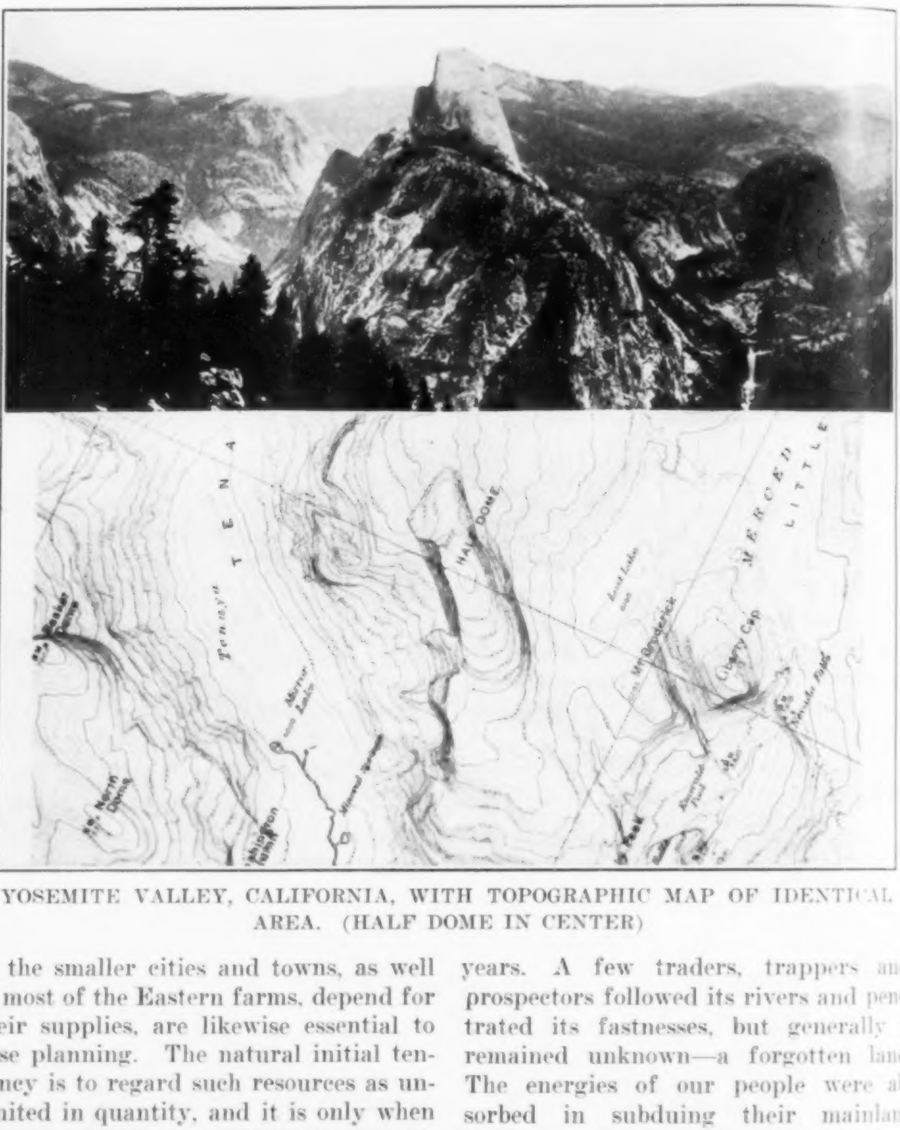
Major Powell was a broad philosophic naturalist rather than a specialist in the field of geology. His years of exploration in the West had stimulated in his eager mind an intense interest in all the problems of the frontier. Among these problems none appealed to him as of more importance than development of the arid and semiarid regions by irrigation. In the 70's and 80's of the last

century it was far clearer to him than to most of his contemporaries that agriculture in the regions of meager rainfall would be restricted to but a fraction of the total acreage by the limitations in the water supply, and that if opportunities for irrigation and reclamation were to be realized, reservoir sites and dam sites must be preserved and accurate information must be obtained about the quantity of water available. His activities resulted in the designation and withdrawal from entry of large areas in the West in the late 80's for irrigation development and in the beginning of systematic studies of stream flow. In recommending these withdrawals, as in many other respects, Major Powell was a generation ahead of his time. His action was bitterly attacked, and most of the areas withdrawn were restored to entry, but the principles that were to be followed in the future had been established and the groundwork laid for later systematic determination of available water supplies. Thus the work of stream gaging was initiated. It has been continued to the present time, and out of it and the early irrigation studies grew in 1902 the reclamation act and later the establishment of the Reclamation Service as an independent bureau.

As the East has become more densely settled, water consciousness has traveled from the arid regions eastward across the continent. Our great cities are now confronted with problems of water supply scarcely less acute than those that confronted the early settlers in Utah or along the meager streams or springs of the arid Southwest. These cities must foresee their needs decades or generations ahead and provide for those needs by acquiring sources of water for their constantly growing populations. So the necessity for accurately determining stream flow and for protecting streams from contamination by industrial wastes or through human occupancy is now recognized in the East as well as in the West. The development of hydroelectric power, to be efficiently planned, also requires knowledge of the available stream flow obtainable only through long-continued observations. Studies of underground water resources, on which many



PACK TRAIN OF A TOPOGRAPHIC PARTY SURVEYING MT. GODDARD QUADRANGLE, CALIFORNIA (1907)



YOSEMITE VALLEY, CALIFORNIA, WITH TOPOGRAPHIC MAP OF IDENTICAL AREA. (HALF DOME IN CENTER)

of the smaller cities and towns, as well as most of the Eastern farms, depend for their supplies, are likewise essential to wise planning. The natural initial tendency is to regard such resources as unlimited in quantity, and it is only when these supplies begin to diminish through overdrafts or become contaminated that the necessity for systematic studies of their limitations and quality is realized. This work too has grown as one of the functions of the Survey and now is practically coextensive with the domain of the United States.

Alaska

After its purchase from Russia in 1867 Alaska was neglected for thirty years. A few traders, trappers and prospectors followed its rivers and penetrated its fastnesses, but generally it remained unknown—a forgotten land. The energies of our people were absorbed in subduing their mainland frontiers. A few private and government exploratory expeditions, which brought out trustworthy records and thus contributed to our knowledge of Alaska's geography and natural history, had been made prior to 1898. The names of Dall, Stoney, Allen, Schwatka, Hayes and Spurr are associated with extensive and heroic explorations of great value. After the gold discoveries in the Canadian Klon-

dike in 1897 came the great gold rush of 1898 and a stimulation of government interest in its northern territory. Hayes in 1891 and Spurr, Schrader and Goodrich in 1896 had represented the Survey in the earlier explorations, but beginning with 1898 the Survey has carried on continuous and systematic work that has now covered about 45 per cent. of the 600,000 square miles included in the territory. Topographic maps and reports on the geology and mineral resources, with incidental information on climate, vegetation and conditions that confront the traveler, are available for all areas where Survey geologists and topographers have been. The broad outlines of the geology and geography of much of this great northwestern salient of the continent are known, and some of the more critical points have been studied in detail.

Much of the work has been done under severe conditions, scarcely hinted at in the laconic and objective reports. The code of the scientific explorer precludes dwelling upon personal hardships and difficulties, which are regarded as all in the day's work, and professional self-respect leads him to foresee, to plan wisely and to execute efficiently, thus avoiding failures and disasters. Hence the record of more than one third of a century of Survey exploration in this remote region is unmarred by a single fatality. On the other hand, it has yielded volumes of reliable information and adequate maps of thousands of square miles for the guidance of those who may follow the survey explorers.

Conservation Activities

Classification of the public lands is one of the duties placed upon the Survey by its organic act. Specific classification as a basis for the administration of the public land laws, however, was not provided for fiscally in the early years of the Survey's existence. This function, therefore, remained dormant until it was vivified under President Theodore Roosevelt early in the present century. Under a policy that he inaugurated and that has been continued since, public lands believed to be valuable for their content of coal, oil or certain other minerals were withdrawn from entry until they could be definitely classified and made available for acquisition under appropriate laws. This practice was later extended to lands valuable as public watering places and stock driveways or for the development of irrigation and water power, and it is now established as a recognized part of public land procedure. During the last twenty-five years Congress has enacted other measures, such as the enlarged and stock-raising homestead laws, that require specific classification as an essential feature in their administration. To meet these responsibilities it has been necessary for the Survey to organize a staff of geologists, engineers and other specialists for the purpose of separating the public lands into the categories recognized in the statutes.

The technical phases of the administration of the various mineral land leasing laws have likewise devolved upon the Survey since 1925. Prior to that time this work had been a part of the duty of the Bureau of Mines, but with the transfer of that bureau from the Department of the Interior to the Department of Commerce on July 1, 1925, the engineering features of the administration of leases of mineral deposits in public lands became one of the Survey's responsibilities. In performing this function, as in that of classifying the public land, it must work in close cooperation with the General Land Office, the office of record and of initial consideration of legal questions involving public lands. The work is built within the framework of general policies controlling all public land matters as expressed by Congress in legislation and

MT. WRANGEL, ALASKA, AN ACTIVE VOLCANO, 14,000 FEET HIGH.

by the Secretary of the Interior in administration.

COOPERATION

In a communication to a state geologist the first director of the U. S. Geological Survey said: "The director desires to announce to you that he urges the inauguration and continuance of state surveys and wishes to cooperate with them to the mutual advantage of both." Thus one of the basic policies of the Federal Survey was announced in 1880. That policy guides its relations with other scientific organizations to-day as it did 53 years ago. Support of state surveys and cooperation with them to the end that there may be coordination in purpose and in results achieved is one of the guiding principles of the federal organization. It realizes that the problems awaiting solution in the field of geology and in other fields occupied by the Federal Survey are almost unlimited and that all the energies—state, local and national—that can be marshaled for their solution and for the services that can be rendered to mankind through research in these fields will be totally insufficient to accomplish the progress that should be made. In 1884 an agreement was made between the Geological Survey and the Commonwealth of Massachusetts for cooperation in the preparation of topographic maps of that state, the costs to be shared equally between the state and the Federal Government. Many such agreements, involving topographic mapping, investigations in many of the fields of geology and the study of water resources, have since been executed. Within the past decade particularly, this method of financing work that both the individual commonwealths and the Federal Government desire to have done has been used extensively and has become a definite policy recognized by Congress in the annual appropriation acts. Approximately a million dollars has been expended during each of the past two years by states and municipalities to the end that high-grade topographic mapping might be expe-

dited and vital studies of water supplies carried on within their borders through the agency of the Geological Survey.

Mother of Bureaus

With the growth of the nation and the increase in complexity of the problems of government, the Survey, through its own initiative or because it has been called upon by Congress or the Administration, has engaged in activities some of which either have not been definitely related to its main purposes or have attained a magnitude worthy of separate recognition. As the value of certain of these activities has come to be recognized, they have been separated from the Survey and delegated to independent organizations. The first of these activities thus to be set apart was that of the study of the cultures of the North American Indians, a study initiated by Major Powell prior to the creation of the U. S. Geological Survey. Throughout his directorship Major Powell maintained a deep interest in this field and created a small organization through which studies of the ethnology of the North American Indians were carried on. Eventually a bureau was established within the Smithsonian Institution for the continuation of this work. Upon his retirement from the directorship of the Survey, on July 1, 1894, Major Powell assumed the directorship of the Bureau of American Ethnology, which he held until his death in 1902.

From the time of its creation the Geological Survey, as an incident to its regular topographic and geologic surveys, had assembled facts on the distribution and character of the timber resources of the West. As a result of this early activity the Survey was called upon, after the enactment in 1891 of the law authorizing the President to set aside forest reserves on public lands, to advise the Secretary of the Interior about areas that might appropriately be thus reserved. In 1897 an appropriation was made for the survey of lands

DAWES GLACIER IN SOUTHEASTERN ALASKA.

then in forest reserves or contemplated for designation as forest reserves, and it was specified that these surveys should be made by the Geological Survey. This work was continued for several years and resulted in a series of reports on forest lands, with maps indicating their appropriate classification. The data thus collected served as a basis for regulations for the administration of these lands, although the administration itself at that time rested in the General Land Office. By 1905 forest reserves were recognized as of sufficient public importance to require the creation of a definite unit of government for their administrative control. Work which prior to that time had been done in both the Departments of the Interior and of Agriculture was combined and transferred to the Forest Service under the Department of Agriculture. Thus the early work of the Survey had much to do with laying the foundations for that efficient unit of government.

Interest in the possibilities of irrigation of the arid lands of the West had, of course, existed since the West became known. Congressional interest had been most definitely indicated by the act of 1888, already mentioned, which provided that lands valuable as reservoir sites and dam sites should be withheld from entry, but the public objection to excluding these large tracts from acquisition at that time retarded the movement for federal irrigation for a decade or more. Nevertheless, the interest then aroused continued, one of its manifestations being the first specific appropriation of $12,500 for the gaging of streams and determination of water supplies, made in 1894. This work, so essential to the effective planning of any irrigation project, was continued and expanded, and finally in 1902 the reclamation act was passed. This act provided for government construction of irrigation works, the costs to be gradually repaid by the owners of the irrigated lands. The reclamation act thus grew out of the earlier studies of the Geological Survey, and its administration was at first intrusted to Director Charles D. Walcott, of the Survey, and remained under his guidance until 1907. In that year, upon his urgent recommendation, the Reclamation Service (now called the Bureau of Reclamation) was created as a separate bureau in the Department of the Interior.

An extensive correspondence, which has never been published, was carried on between Clarence King, the first director of the Survey, and Dr. Carl Barus, one of the most distinguished among American physicists at that time, about the possibility of locating ore bodies underground by measuring electrical conductivity between two or more distant points. Indeed, an unsuccessful experiment was actually made in the field in an endeavor to make use of this method of ore finding. Interest of the early geologists of the staff in the possibility of combining physical and geological methods was not, however, abated because of the failure of this first experiment. It became clear to these thinkers that a long, slow series of investigations in the general field of geophysics must be carried out before successful practical applications could be expected. Minor beginnings were made in such work, but all these studies were abandoned in 1892 with the severe decreases effected that year in funds available for the Survey's work. Eight or ten years later it became possible to give further consideration to the general problem, and from 1900 to 1906 a moderate amount of research on this subject was carried out in the Survey laboratories. The experiments had become sufficiently promising by 1904 to induce the Carnegie Institution of Washington to aid the research with a grant of money, and by 1906 the work was placed upon a permanent basis by the Carnegie In-

stitution through the establishment of its Geophysical Laboratory, to which the work theretofore carried on by the Geological Survey was transferred. The highly important scientific results attained in this laboratory during the past quarter of a century are, of course, to be attributed to its able director and admirable staff, yet the Geological Survey had no small part in its beginnings.

It was inevitable that the work done by the Survey in the mining regions of the West should bring it into close contact and sympathy with mining problems *per se*—that is, the problems of the mining engineer in the recovery and treatment of ores. The Survey's own logical field is not that of recovery or treatment of ores but that of ore bodies as geologic units—their occurrence, their geologic environment, the reasons for their existence and the possibilities of the existence of other bodies and their probable locations. Mining men, however, have repeatedly expressed the desire that the Survey expand its work beyond that of the geology of the ores to include the problems of recovery. In response to this need there grew up within the organization, at the beginning of this century, a technologic branch, which dealt more specifically with the problems of the mining engineers. This branch proved its usefulness to the mining industry and eventually was recognized as of bureau status and separated in 1910 as the Bureau of Mines.

The Survey takes much pride in these vigorous and useful organizations that have grown out of its own earlier activities, and it also takes pride in the fact that, throughout its career, it has adhered so far as possible to its own main lines of endeavor. As the activities extraneous to these main lines have developed and proved their usefulness, it has welcomed their recognition as additional units of government.

Funds

Scientific readers need not be told that the very nature of scientific work is such that continuity and certainty of such financial support as is extended is essential. The certainty of support is almost more important than its magnitude. The studies that promise greatest value should not only be carefully planned but continuously supported to completion. The universities and the foundations, in this respect, have a distinct advantage over publicly supported research groups. Legislative bodies, state or national, however sympathetic they may be with long-continued studies of the research type, find difficulty during periods of economic stress in providing funds for work that does not have an obvious, immediate and direct bearing upon a state or national need. During periods when treasuries are well filled the desire which prevails among many of these bodies to support research as a proper part of governmental activity can be realized without great difficulty, but in times of fiscal depression, when there is an almost irresistible public demand for the reduction of so-called "non-essential" public activities, it quite naturally appears to them that the research type of work can be deferred. It is by no means always appreciated that to carry such work forward fruitfully requires long, slow and careful selection of well-trained staffs, and that as these staffs gain experience their value and the likelihood that they will make contributions that will ultimately result in great national benefit increase with the passage of time. The dispersal of such staffs and the consequent interruption or abandonment of the projects on which they are engaged results in irreplaceable loss, so that fluctuations in funds from year to year, now up and now down, create a fiscal environment that is most inimical to valuable research.

The Survey, like all scientific organizations supported by appropriations, is affected by these adverse conditions. Perhaps the surprising thing is that it has not been even more seriously affected. Nevertheless, there have been periods in its history, of which the present may prove to be one, that have been very adverse to orderly scientific work.

The appropriation available to the Survey for the first year of its existence, namely, the fiscal year 1880, was $106,000. This amount was slowly increased during the next decade until it reached $879,000 in 1890. Then began a period of decline, culminating in 1893 and 1894, when appropriations of $488,000 and $495,000, respectively, were made for its activities, which by that time had become rather complex. Another period of slow growth then began until in 1909 the appropriations available to the Survey amounted to $1,800,000. This was followed by another decline to less than $1,500,000 during 1912 and 1913. Although during the world war a large portion of the Survey's energies were absorbed directly and indirectly in special war services, it did not participate in the appropriation increases that were so general during that period, and after the war, in 1919, its total appropriations aggregated slightly less than $1,438,000. The sums available during the next few years fluctuated in general only by the amounts added to enable the Survey to discharge additional duties thrown upon it. The chief of these additional duties was the administration of the mineral leasing laws transferred to it from the Bureau of Mines in July, 1925. Moreover, a policy of Congress which began to be effective toward the end of the decade 1920–30—the policy of meeting on an equal basis the coöperation offered by states and municipalities—required increases in the federal funds for topographic mapping and investigations of water resources. These factors, together with moderate additions to funds for research work and for publication, eventually brought the appropriations to their high-water mark of $3,141,000 in the fiscal year 1932. Since then the great drop in federal revenues and the response of Congress to this drop through its reduction in federal expenditures brought the funds available to the Survey in 1933 down to $2,615,000, and the act as passed by the present House proposes to reduce the amount available for 1934 to $1,927,500. The most regrettable feature of these decreases is the fact that they fall so heavily upon the Survey's basic research work and upon the publication funds, through the use of which the products of its activities become available to the public, to educational institutions and to industry.

THE OFFICE OF EDUCATION

By Dr. WM. JOHN COOPER
U. S. COMMISSIONER OF EDUCATION

THE Constitution of the United States makes no mention of education. How, then, does it happen that we have an Office of Education in the Department of the Interior? This question troubles many people, especially those who are fearful lest there be set up in this country a department of education similar to those which function in some European countries. As a matter of fact, the Constitutional Convention did discuss the inclusion of education among the powers given to the Federal Government, but reached the conclusion that, though very important, education was a subject which each state could handle in its own way.

Federal interest in education may be said to date from the census of 1840, which was the first census to gather any figures on illiteracy in the United States. This action was due to the vision of Henry Barnard, secretary of the board of education of Connecticut. Dr. Barnard had traveled around over the country, lecturing in various states, and he realized how little we knew about the systems of education which had developed in the different states.

Therefore, in 1838 he came to Washington and conferred with various members of the Secretary of State's office, which, at that time, had charge of the census. Eventually he reached Mr. Hunter, who had the preparation of the schedules of the 1840 census in hand. He induced him to incorporate into the inquiry form certain questions which would show the condition of literacy in this country. By order of Congress the results of this inquiry were sent in manuscript to Dr. Barnard as soon as tabulated, and in 1841, on the basis of these returns, he prepared an address on "The Magnitude of the Educational Interests of the United States and the Necessity of Great and Immediate Improvement in State and City Systems of Public Instruction." This address aroused Horace Mann and other leading educators of the time to emphasize the need for more public schools. From this time on to 1867, Barnard himself consistently urged a department of education in the Federal Government.

In 1845 and again in 1847 Barnard endeavored to get "the diffusion of a knowledge of the science and art of education, and the organization and administration of systems of public schools into the plan of the Smithsonian Institution." On October 17, 1849, a convention met in response to a call for "a national convention of the friends of common schools," signed by Bishop Alonzo Potter, of Pennsylvania, Horace Mann, Henry Barnard, and others. At this meeting the following resolutions were adopted: "*Resolved*, That a committee of five be appointed to prepare a memorial to Congress, asking the establishment of a bureau in the home department for obtaining and publishing annually statistics in regard to public education in the United States." At a meeting of the officers of the American Institute of Instruction held at Lynn, Massachusetts, on January 4, 1851, a committee was appointed "to consider the expediency of petitioning Congress with reference to the establishment of an educational department at Washington."

At the fourth meeting of the American Association for the Advancement of Education, held in Washington, Decem-

HENRY BARNARD
COMMISSIONER OF EDUCATION, 1867–1870.

ber 26, 1854, a resolution was passed approving the distribution of lands for the support of education. In addition to this, it was asserted that "it entertains the strongest convictions that the interests of public education will be greatly advanced by the establishment in connection with one of the departments of government of a depository for the collection and exchange of works on education and the various instrumentalities of instruction."

Commenting upon the reorganization of educational associations which occurred with the formation of the National Teachers Association in 1856, Dr. Mayo said, in reference to the American Association for the Advancement of Education, "All proceedings of this body of educators, which only dissolved on the organization of the National Teachers Association in 1856–58, had but one logical tendency—that in some way the National Government should interest itself again in the education of the whole people."

At the meeting of the National Teachers Association in Cincinnati, on August 11, 1858, President Z. Richards delivered an address in which he said in part: "The subject of a national bureau of education, to be connected with the Department of the Interior at Washington, has often been spoken of, and urged, as worthy of Congressional legislation. . . . We believe, however, in common with some of the wisest and most considerate friends of education, that a special effort should be made to establish at our national metropolis a *central and national educational agency*, by the aid of which more efficiency and uniformity of character may be secured in the educational movements of our country; and a library of educational books and publications collected from every part of our country and the world."

The following year Mr. Valentine moved a resolution: "*Resolved*, That a committee of three be appointed to confer with the Honorable, the Secretary of

JOHN EATON
COMMISSIONER OF EDUCATION, 1870–1886.

the Interior, to ascertain what additional statistics in relation to the subject of education are desirable and feasible to obtain by means of the approaching national census." In 1860, this same association, meeting in Buffalo, from August 8 to 10, was advised in the introductory address of President J. W. Bulkley that Congress be urged to inaugurate a department of public instruction. "With such a department," he said, "having the necessary appliances, and an intelligent and efficient head, we can hardly estimate its power and influence."

The Civil War interrupted for a time agitation along this line, but when the National Teachers Association met at Ogdensburg, New York, from August 10 to 12, 1864, Professor S. H. White read a paper on "A National Bureau of Education" and offered a resolution which read: "*Resolved*, That in the opinion of this association, the educational interests of the country would be greatly advanced by the establishment of a national bureau of education." A committee of three was appointed to attend to the details.

The next year, at a meeting held at Harrisburg, Pennsylvania, Professor Rickoff declared "that Congress, at the very next session, should establish an educational department, and authorize the President to appoint a Commissioner of Education."

In February, 1866, the National Association of State and City School Superintendents met in Washington, D. C., and urged the creation of a national bureau of education. They appointed a commission, consisting of Dr. E. E. White, state commissioner of common schools of Ohio, Newton Bateman, superintendent of public instruction of Illinois, and J. S. Adams, secretary of the state board of education of Vermont, to memorialize Congress to this effect. This committee met immediately following the adjournment of the association and prepared a memorial of some two pages. This was presented to the House of Representatives by General James A. Garfield, Congressman from Ohio, on February 14, 1866. At the same time he presented a bill establishing the National Bureau of Education. In the debates which followed it was suggested that a department instead of a bureau be created, and this bill received 80 votes in its favor with 44 against it in the House on June 19, and was sent to the Senate. Here it came before the committee on the judiciary, was favorably recommended, and on March 1, 1867, it passed without a division. The following day it was signed by President Johnson, and on March 14, 1867, Henry Barnard became the first commissioner of education.

The functions to be performed by the new office were defined in this original act as follows: "to collect statistics and facts showing the condition and progress of education in the several States and Territories, and to diffuse such information respecting the organization and management of schools and school-systems, and methods of teaching, as shall aid the people of the United States in the establishment and maintenance of efficient school-systems, and otherwise promote the cause of education throughout the country."

The fact that the original bill had called for "bureau" and a "department" had been created aroused some Congressmen against it. Moreover, some schoolmen failed to understand the act. There was so much opposition that in the appropriation act passed on July 20, 1868, a provision was inserted abolishing the Department of Education as a separate unit and recreating it as an Office of Education in the Interior Department. This bill also reduced the salary of the commissioner from $4,000 to $3,000 a year. This act became effective on July 1, 1869. Dr. Barnard at once tried to arouse the educational

NATHANIEL H. R. DAWSON
COMMISSIONER OF EDUCATION, 1886–1889

associations to protest to Congress. When, however, there seemed to be general apathy on the subject, he resigned, effective on March 15, 1870.

Dr. Barnard had faced an almost impossible test. The elementary schools in the North had suffered during the war, and those which had existed in the South had been completely wrecked. The "New West," which was rapidly settling up, needed much aid in shaping its schools. To do all this work the commissioner was given a force of but four employees and funds amounting to slightly in excess of $12,000 to cover salaries and expenses for two years. With this meager allotment he made an extensive survey of the schools of the District of Columbia. But the work which he did as commissioner consisted of examining the history of educational experiments, the dismissal of educational reformers and the biography of great teachers. During most of the time that he was in office the Secretary of the Interior was hostile to him. The *Congressional Globe* of November 30, 1868, quoted the secretary as favoring the elimination of the Department of Education on the ground that there was no necessity of knowing anything whatsoever about it. Nobody had ever come to an office with greater enthusiasm and more practical experience than Dr. Barnard brought; nobody ever met with more disheartening experiences than he did.

When he retired on the 15th of March, President Grant appointed General John Eaton, of Tennessee. He was destined to serve for more than 16 years. He possessed ability to get cooperation from the Congress, which Barnard had failed to do. In his addresses to the National Education Association he called attention to the powers of his office. On the negative side of the question he said, "The National Government should take no action calculating to decrease local or individual effort for education. It is of the individual and by the individual but it is for all men.

WILLIAM TORREY HARRIS
COMMISSIONER OF EDUCATION, 1889–1906.

OFFICE OF EDUCATION IN THE TIME OF DR. HARRIS.
LOCATED ON NORTHEAST CORNER OF EIGHTH AND G STS. OPPOSITE THE OLD BUILDING OF THE DEPARTMENT OF THE INTERIOR.

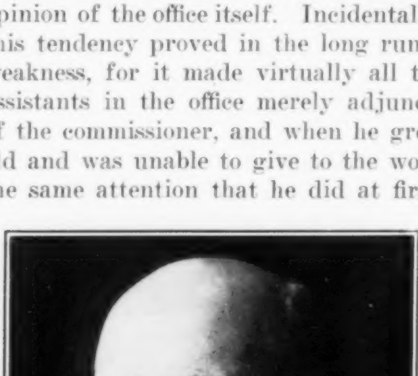
The National Government in its relation to public education may not suffer either the local or general problems of ignorance that shall result in the destruction of the principles of liberty by the centralization of power." On a platform similar in content every commissioner of education has stood. These principles have served as a guide for the work which should be performed in the office. Eaton represented the Department of the Interior at the Centennial Exposition in 1876, was chief of the Department of Education for the New Orleans Exposition, and was president of an International Congress of Education held there. During his term the library was very largely increased. In 1870, in addition to Dr. Barnard's books, there were not over 100 volumes. But when Eaton left there were 18,000 bound volumes and 47,000 pamphlets. Moreover, the assistants in the office had increased from 2 to 38, for during his term statistical work had been begun and the educational service in Alaska assumed.

He resigned on the 5th of August, 1886, and Nathaniel H. R. Dawson, of Alabama, was appointed by President Cleveland. Colonel Dawson began his new work on September 27. Many criticisms were leveled at this appointment, not at the man nor his personal qualifications, but at his lack of educational qualifications for the office. Recognizing this, he endeavored to select as his assistants people of practical experience in education. Under his personal direction a series of monographs on the history of education in the several states was begun. Some of these, prepared under the direction of the history department of Johns Hopkins University, are still authentic documents in the field.

Dawson resigned on September 3, 1889, and was succeeded by William Torrey Harris, of Massachusetts, who had been superintendent of schools in St. Louis, Missouri. Dr. Harris was an outstanding commissioner. He was the American authority on the works of Hegel, and his explanations of Hegel's

philosophy won him an honorary Ph.D. degree from a German university. When Spencer's "First Principles" appeared, Harris wrote a review, but unable to find a journal which would accept it he founded *The Journal of Speculative Philosophy*, which he edited from 1867 to 1893. During his term the work in foreign education was begun and took on very great importance. It was also while he was commissioner that the second Morrill Act was passed. He had not only the longest term in the history of the office, but also when he came in was so well known from the point of view of his leadership and his grasp on education that correspondence which came into the office asked the commissioner's opinion rather than the opinion of the office itself. Incidentally, this tendency proved in the long run a weakness, for it made virtually all the assistants in the office merely adjuncts of the commissioner, and when he grew old and was unable to give to the work the same attention that he did at first,

DR. PHILANDER P. CLAXTON
COMMISSIONER OF EDUCATION, 1911–1921.



DR. ELMER ELLSWORTH BROWN.
COMMISSIONER OF EDUCATION, 1906–1911.

the office suffered. He also failed to give sufficient attention to Congress, with the result that his successor found the committee on education entirely out of touch with the work of the office.

When Dr. Harris aged and his health began to fail, the matter of a retirement salary for him was taken up by his friends with the Carnegie Foundation for the Advancement of Teaching. When they were ready to give him a pension he resigned on June 30, 1906, and was succeeded by Elmer Ellsworth Brown, of California. Brown immediately gave his attention to the problems of internal organization, securing a man from the Congressional Library to put the library of the Office of Education on a workable basis; brought the reports, which were from one to three years late, up to date, and began the issuance of a series of bulletins which had been authorized 10 years before. He brought the office work to the attention of the Secretary of the Interior and Congress and attempted to secure for the office

additional specialists in various fields. Some of these he obtained. The specialists in higher education, rural schools, school hygiene and industrial education and the editor-in-chief were obtained at this time. In addition, a lump sum of $6,000, the first the office had ever enjoyed, and which became available after he had left the office, was granted. The salary roll increased during his term almost $20,000, and the commissioner's own salary was advanced from $3,500 to $5,000. In May, 1911, he submitted his resignation to become effective on June 30 following, on which date he became chancellor of New York University. He was succeeded by Philander P. Claxton, of Tennessee.

Dr. Claxton had come from his work in North Carolina and Tennessee with all the enthusiasm of a missionary. He was an authority on the rural school and greatly strengthened the work of the division. During his time, however, came the great world war, and with it a large number of a-dollar-a-year men and women were appointed. Occasionally people were put on the payroll at a dollar a year and given appointments on the staff who were really paid secretaries of educational organizations. At this time, the work of this office may be said to have been (1) to collect expert opinion and statistics on education and to disseminate these among the several states; (2) to serve as an expert adviser to local governments and to colleges on educational matters; (3) to conduct research in education; (4) to approve the allotments to and the disbursements of the land-grant colleges under the Morrill-Nelson acts; (5) to direct the educational processes for the natives of Alaska; (6) to superintend the reindeer industry of the Alaskans; and (7) to furnish medical aid to the natives of Alaska. Of these duties the last four groups may be said to be administrative; the first three are essentially research.

There had been added during Dr. Claxton's administration a number of specialists for war work, and such work also involved almost the full time of some of the other specialists. For instance, the division of home economics did a great deal of work in connection with the preparation of foods which people in this country had to use while their own white flour was being shipped abroad. It had also a big field in the war propaganda. Another large field of work was the encouragement of school gardens used to produce food for Americans, while food commercially produced was shipped abroad. Thrift stamps had to be sold, instruction in citizenship worked out, and an effort made to get foreigners naturalized. In all this work the Office of Education was exceedingly active. A travel fund had been voted by Congress which enabled Commissioner Claxton to visit many parts of the country and he addressed associations on the work of the war especially.

In June, 1921, he resigned and John James Tigert assumed responsibility. At this time much of the work which Claxton had done was eliminated. Appropriations for printing were reduced and expenses of government in other respects were curtailed. All the dollar-a-year men were dropped or taken over as assistants in the commissioner's office. The citizenship work, which had been going on under Dr. Dunn, was assumed by the American Red Cross. During this administration the Bureau of the Budget was created and every effort was made to hold down the expenses.

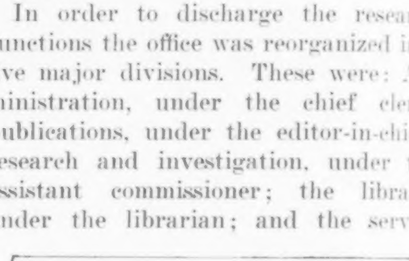
On the 31st of August, 1928, Commissioner Tigert resigned to become president of the University of Florida. The present commissioner took office on the 11th day of February, 1929. After a brief study of the situation it was decided to make the office essentially a research office, which it had been at the time of its creation. The name "Bureau

DR. JOHN JAMES TIGERT
COMMISSIONER OF EDUCATION, 1921–1928.

of Education," which had been used in the appropriation acts and for which there was no other authority, was abandoned in favor of Office of Education on an order of the Secretary of the Interior.

The commissioner visited Alaska the first summer he was in office and investigated the schools and other work as far as he was able. This convinced him that Alaskan affairs could not be successfully handled by the Office of Education. Accordingly, on November 1, 1929, by order of the Secretary of the Interior, the reindeer service was transferred to the Governor of Alaska, thereby placing it in the hands of a local officer who could give it the necessary attention promptly. During the formulation of the appropriation act of 1930 he made an effort to have the education of the natives of Alaska transferred to the commissioner of education of the territory. In this, however, he was unsuccessful, largely for the reason that members of Congress desired some Federal officer to be responsible to them for the expenditure of the funds. It was then decided to have the education and the medical service for the Alaskans transferred to the Indian Office, which has supervision of matters relating to the Indians in continental United States. In the second deficiency act of 1930, this was also accomplished. With this transfer of work the assistant chief clerk and the assistant head of the Alaska division were transferred to the Indian Office. From this time on the Office of Education had only the allotment and disbursement of land-grant funds in addition to the original research functions for which it was created.

In order to discharge the research functions the office was reorganized into five major divisions. These were: Administration, under the chief clerk; publications, under the editor-in-chief; research and investigation, under the assistant commissioner; the library, under the librarian; and the service



DR. WILLIAM JOHN COOPER
COMMISSIONER OF EDUCATION, 1928–

division, under the chief of that division. This last division includes all those specialists whose field lies in more than one of the other divisions. It also covered the surveys of states and cities which had been begun in Commissioner Brown's time and which had been found useful to the office in keeping its members closely in touch with affairs in the field.

The major division of research and investigation was further subdivided into five minor divisions: (1) A division of colleges and professional schools which succeeded to the work formerly handled by the higher education division. This involves certain special statistics of the colleges and universities, the land-grant college statistics which are required by law, dealings with the professional associations and surveys of institutions or of states so far as the collegiate institutions are concerned. (2) The division of American schools which succeeded to the work of the former city schools division, and also to that of the rural schools division in so far as these rural schools presented similar problems. (3) The division of special problems which took over the rural school problems of transportation and other problems due chiefly to sparseness of population, and added to these the education of children who are physically or mentally handicapped and those who are supernormal. To it also were assigned Negro education, which had existed as a division in Commissioner Claxton's time, and the education of indigenous peoples, as the Office of Education had control of the natives of Alaska for 40 years and had made great progress in the vocational education of these people, but had not really made a fundamental psychological study of them. (4) The division of statistics which had grown up gradually; and (5) the division of foreign schools which had only about half enough assistants.

As soon as it is possible for Congress to vote more money, we wish to add to the divisions the following specialists: To the service division, a specialist on extension education; to the division of American schools, a specialist on school supervision; to the division of special problems, an expert in the education of indigenous peoples; and to the foreign schools division, two experts—one on the schools of the Orient and another on the schools of Spanish America. The addition of these five specialists will make the Office of Education a reasonably efficient workable organization. To them should be added a few assistants.

In making the office a strictly research organization, it became necessary to get funds from Congress to pursue the following projects. The first one attempted was a National Survey of Secondary Education, authorized by Congress in 1929. It was decided to have a new division in the office whose personnel would be temporary, with the exception of one man who would be the man regularly employed in the office for that piece of work. Two hundred and twenty-five thousand dollars were appropriated to be spent over a period of three years. It was found upon investigation of the plan submitted by the National Committee on Research in Secondary Education that it would give no information on the history of secondary education, on the aims and purposes of education, on teachers of secondary schools or on the costs of such schools. It was decided, however, to omit the history of education. The aims and purposes of education, it was felt, would be largely copies of the cardinal principles which were published by the office in 1918. The teachers and the costs of secondary schools could be gathered in other surveys along with the costs and teachers in other schools. Accordingly, the survey gave its attention to the curriculum, the extra curriculum, the organization of administration, guidance and similar problems. Dr. L.

V. Koos, of the University of Chicago, an outstanding man in the field of secondary education, was made part-time associate director and was allowed to build up his staff both with part-time and full-time workers. The money was appropriated, $50,000 for the first year, $100,000 for the second year and $75,000 for the third year. These amounts included the printing, as well as all other expenses of the survey.

In 1930 Congress authorized $200,000 for a survey of the education of teachers. This also was distributed over a three-year period, but for the third year the appropriation was cut by $20,000, making $180,000 available for the entire study. Likewise for this survey the member of the staff who had teacher education in hand was assigned as coordinator. Dr. E. S. Evenden, of Columbia University, was obtained as part-time associate director. The work of this survey will be practically finished on June 30 of this year.

The third survey, in school finance, was approved in 1931 for $350,000, distributed over a four-year period. Dr. Paul R. Mort, of Columbia University, was secured as part-time associate director, and the specialist in school finance in this office was assigned as the coordinator. At the end of the first year of this study, the financial crisis made it desirable to balance the budget. In attempting to do this Congress eliminated this study entirely. As a result only one volume, a bibliography of educational finance, was published from Government funds. Of the five fields which had been outlined for investigation, one only could be brought to a conclusion and to do this required more funds. In this emergency the General Education Board's executive committee granted us all the money which the committee could grant. With this fund two more volumes are being published: One, on the state support of schools, will bear the imprint of Teachers College, Columbia University, and will be widely distributed free. All other problems which had been started in the other four fields will be published under an imprint of the American Council on Education and sold to persons who are interested. This volume will be entitled "Research Problems in American School Finance."

While the depression has temporarily put a stop to this special survey work, which was directed by the commissioner personally, it is hoped that when the government finances are in better shape it will be possible to resume surveys of this sort.

A survey of special education had already been discussed and approved by the state superintendents of public instruction. A survey of elementary education was in the process of formulation. These two surveys as well as the study of school finance should be taken up as soon as funds permit and carried to a conclusion.

SADI NICHOLAS LÉONHARD CARNOT

Professor E. H. JOHNSON

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SADI NICHOLAS LÉONHARD CARNOT was born in Paris on the first day of June, 1796, the eldest son of the noted French mathematician, Lazare Nicholas Marguerite Carnot. Surrounded by a family whose members through several generations had held political and military posts of the first importance, Sadi Carnot's brief life was denied no essential for brilliant achievement. It was natural that he should display the mental acuity that was a family characteristic, although his latent abilities did not find their proper outlet until after he had left the fields in which his forbears had found lasting fame and turned to scientific investigations.

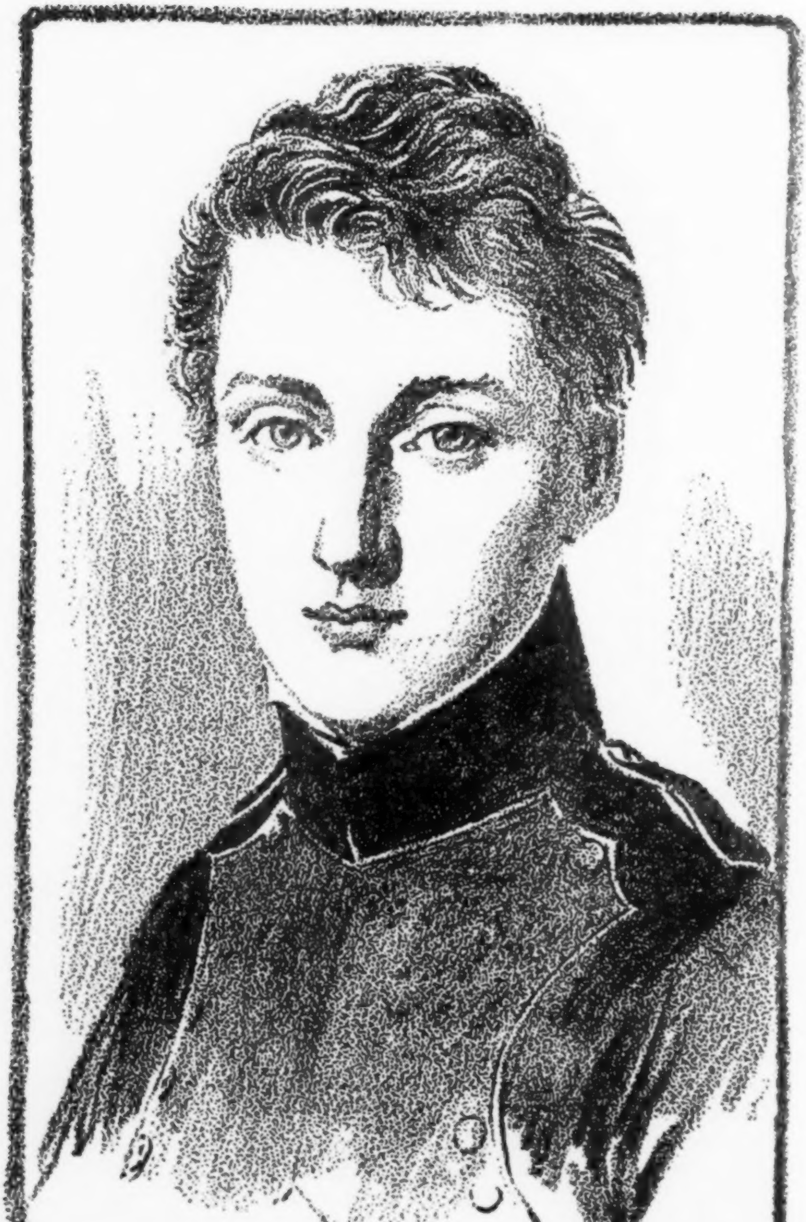
At the age of sixteen years, Sadi entered the École Polytechnique, having in view a career as a military officer. Two years later he went out from the institution commissioned as an army engineer and with excellent prospects for promotion, but the downfall of the Empire and the Bourbon Restoration brought such family reverses that he left this branch of the service in disgust. The duties assigned to him under the changed régime were not only irksome, but they allowed no time for private study and offered little hope for improvement in the future. Consequently, in 1819, Carnot turned to the staff corps, where he won a lieutenancy on his showing in the usual examinations.

It was during the next few years that his health seems to have been undermined beyond repair, so ardent was his application in the pursuit of knowledge. His studies took him into the fields of mathematics, physics, chemistry, natural history, political economy, music and the fine arts in general. Apparently, he drove himself without mercy. Long periods of intense study were broken only by like excesses in athletics, especially swimming and fencing. His physique was never robust, and it was inevitable that such continued and heavy demands on both mind and body should lead to a final breakdown.

For a number of years cholera had been epidemic throughout the Far East, India and Asia Minor. In January, 1832, it reached London, and soon thereafter it appeared in France, Spain and Italy. It was during this year that Carnot fell a victim to scarlatina, which ran into brain fever. And then, before he had fully recovered, he was overtaken by the dread Asiatic epidemic, and he died in Paris on August 24, 1832. Thus, after a span of only thirty-six years, ended the physical career of "one of the most original and profound thinkers who have ever devoted themselves to science."

To appreciate the justification for such a sweeping assertion, it is necessary to survey not only his own work, but also some of the theories of his predecessors, and the remarkable developments that have followed during the century since his death.

From ancient times there have been numerous speculations concerning the nature of heat. For present purposes these may be grouped under two general theories. One of these regarded heat as a fluid substance, and, although it was overthrown during the first half of the nineteenth century, our present terminology retains many reminders of this view-point, such as "flow of heat," "quantity of heat," etc. The other theory, possibly equally ancient in its



From a portrait by Bailly.

SADI NICHOLAS LÉONHARD CARNOT (1796–1832)

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beginnings, regarded heat as some sort of motion. Plato (427–347, B. C.) declared that heat and fire are themselves due to motion. Several hundred years later, Titus Carus Lucretius (95?–55, B. C.), a Roman didactic author, wrote a remarkable poem entitled "De Rerum Natura," and in it he discussed heat as a kind of substance. In his "Novum Organum," Francis Bacon (1561–1626) declared that "heat is motion"—it is the movement of the "perpetually quivering" small parts of bodies. This latter view seems to have been accepted by the majority of Bacon's English followers, although in Continental Europe many philosophers still preferred to regard the heat in a body not as the motion of its own particles, but rather of the particles of a peculiar fluid that found ready passage through the pores of the body. To account for various observed phenomena, this fluid was regarded as a highly elastic and very subtle substance. However, in 1664, Robert Hooke, in his "Micrographia," stated that heat is "nothing else but a very brisk and vehement agitation of the parts of a body." Apparently, this view was not uncommon during the seventeenth century, numbering among its adherents Descartes, Amontons, Boyle and Newton.

In spite of these leanings towards the modern energy theories, many philosophers during the seventeenth and eighteenth centuries clung to the material theory of heat. In 1756 Joseph Black, who was professor of chemistry at Glasgow University, investigated the problem of the disappearance of heat when ice melts and when water boils. Such a change of state is not in itself accompanied by a change in temperature, although a large amount of heat is absorbed in the process. Black regarded heat as a fluid substance, and he came to the conclusion that its disappearance was due to a sort of chemical union with the substance being melted or boiled. Hence, he termed this heat "latent," *i.e.*, hidden, as distinguished from the "sensible" heat that affects a thermometer. We now know that there is no "latent" heat, but merely a transformation by which the thermal energy being supplied to cause the melting or the evaporating increases the potential energy of the particles of the substance. Nevertheless, the material theory of heat seemed to have gained some support, and, considering the dearth of conclusive experiments, it is not surprising to find it widely accepted in Carnot's time. The temperature of a body was thought to depend on the quantity of heat-substance or "caloric" it contained. At the same time it was believed that the total quantity of caloric in the universe was unalterable. Some investigators believed that thermal conduction was due to the self-repellent characteristic of the particles of caloric, perhaps aided by an attractive force between them and the particles of the conducting body. Naturally, caloric was at first believed to possess the common characteristic of all matter, namely, weight, but in 1799, Count Rumford made his famous "Inquiry Concerning the Nature of Heat," in which he carried out a series of painstaking and delicate experiments that brought him to the conclusions that "a body acquires no additional weight upon being heated, or rather, that Heat has no effect whatever upon the weight of bodies," and furthermore that "all attempts to discover any effect of Heat upon the apparent weights of bodies will be fruitless." Rumford further decided that it is "extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner the Heat was excited and communicated in these experiments, except it be motion." In other words, he regarded the heat generated in his tests as a transformation of the work done in its production.

At about the same time that Rumford was carrying on these investigations, Humphry Davy succeeded in melting two blocks of ice by merely rubbing them together so that their friction was the only source of the heat causing the melting. The conclusions seemed unavoidable, and the calorists were forced to accept them in part, at least in so far as the question of the weight of heat was concerned, and thus it was that caloric became one of the imponderables.

Still there were others, who, like Rumford, had a growing suspicion that there was a definite relation between work and heat. Ignorance of this relationship, or, as we now say, of the principle of the conservation of energy, had for centuries led many serious workers to attempt the making of perpetual motion machines. Nineteenth century experimental technique had to undergo several decades of development before the mechanical equivalence of heat could be determined with such quantitative precision as to bring universal acceptance of an energy theory. When, however, it finally became certain that heat was not a material substance, and that energy could only be transferred, the search for self-motivating devices that also should act as perpetual sources of power came to an end, so far as intelligent investigators were concerned. But before leaving the point, it should be noted that the actual measurement of the equivalence between work and heat was a step quite distinct from the recognition of the immaterial nature of heat.

At the time when Carnot began his famous investigations in this field neither the non-material nature of heat nor its mechanical equivalence had been demonstrated conclusively. Being an engineer, he naturally was interested in the problem of how much work might be obtained from a steam engine. He not only began by accepting the still-prevalent caloric theory, but also the doctrine of its conservation, although the experiments of Rumford and Davy had indicated that heat was actually generated. And yet, we scarcely can say that these views were serious handicaps, for he saw that the basic problem was one of much wider application than to the steam engine alone. Its treatment should be general enough to embrace all heat motors, of any type whatsoever—a conviction that was expressed early in his paper of 1824. Although this was his only publication, the "Reflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance" stands as a classic, because of its keen analytical style, as well as the importance of its conclusions. Carnot began by declaring that "in order to consider the generation of motion by heat in all its generality, it is essential to reason independently of any particular mechanism or special agent; the conclusions obtained must be applicable not only to the steam engine, but to any imaginable heat motor, whatever be the working substance employed, or the method of its use." When one considers the possible scope of such a problem, it is not surprising that its solution over a hundred years ago should have had a wide influence upon the developments of the century that now has elapsed.

In building up his general argument, Carnot discussed the performance of the steam engine in some detail. He maintained that the production of motion is always accompanied by the restoration of thermal equilibrium, *i. e.*, by the passage of heat from a hot body to a cooler one. Thus, he pointed out that in the steam engine

> the heat produced by combustion penetrates the walls of the boiler, and generates steam, in which it becomes incorporated, so to speak. This steam carries heat with it to the cylinder, where it does a certain amount of work, and from there passes on to the condenser, where it is condensed by contact with the cold water. In this final stage the heat that was generated by the combustion is absorbed by the cold water of the condenser. It is heated by means of the

steam just as if it had been placed directly over the fire. The steam is only a medium for the transfer of the heat.

Carnot believed that it was the transfer of heat rather than its destruction that resulted in work. On this point he said:

The generation of motive force in a steam engine is not due so much to the actual consumption of heat, as to its passage from a hot body to a cold one, *i.e.*, to the restoration of its equilibrium, which by some means, such as chemical action, combustion, or in any other way, has been disturbed. . . . This principle applies to all machines that are set in motion by means of heat.

Again:

In general, whenever a temperature difference exists, and where it is possible to restore temperature equilibrium, a moving force can be produced. Steam is one means for acquiring this force, but not the only one; all substances in Nature can be used for this purpose; all are subject to volume changes, successive contractions and expansions with alternations in their warmth and coldness; by these volume changes, all are capable of overcoming certain amounts of resistance, and in this manner of producing moving forces. A solid body, such as a metal rod, increases and decreases in length if it is alternately warmed and cooled, and it is able to move bodies attached to its ends. A fluid that is alternately heated and cooled undergoes an increase or a decrease in its volume, and can move bodies of considerable weight that may oppose its expansion. Temperature variations produce large changes in the volume of a gas if it is in a flexible container, such as a cylinder provided with a piston, and can produce considerable movement. The vapors of all substances that can exist in the gaseous state . . . may be used in the same manner as steam.

The above statement shows clearly that at the time it was written (1824), Carnot had in mind only the transfer of heat without loss, from a higher to a lower temperature. He was thinking of the falling of a material substance (caloric) from a given temperature level to a lower one, whereby it is enabled to do work, just as water turns a wheel by falling from a height without any alteration in its quantity. However, in some of his later miscellaneous notes, which were first published in 1878 by his brother, L. H. Carnot, there is evidence that he afterwards abandoned this idea of the conservation of heat, and gave some thought to the "mechanical equivalence" of the heat used in doing the work. These notes also show that somewhat prior to 1832 (the time of his death) he had acquired a true conception of the nature of heat, and had projected a number of experiments similar to those actually performed years later by J. P. Joule in determining the numerical value of the mechanical equivalent of heat, that is, the number of foot-pounds of work necessary to raise the temperature of one pound of water through one Fahrenheit degree. His plans even anticipated the famous "porous plug" experiment of Joule and Thomson.

However, we must bear in mind that at the time the "Reflexions" was written, Carnot insisted on the conservation of the heat employed in the cyclic transformation in a heat motor. His emphasis on this point is best appreciated by reading his own words:

In our considerations we must insist that if a body undergoes any changes, and, after a series of transformations, returns to its original condition of density, temperature and molecular state, it then contains the same quantity of heat as it had originally,—in other words, the quantities of heat absorbed and evolved during the various transformations completely balance one another. This fact has never been doubted; at first it was accepted without reflection; later it was verified by numerous calorimetric experiments. To deny this is to set aside the entire theory of heat, of which it is the basis. However, it may be remarked that the principal foundations on which the theory of heat rests stand in need of much more thorough investigation. The theory in its present state is unable to explain numerous observed facts.

The latter part of this quotation might lead one to think that Carnot was about to abandon the caloric theory in favor of one based on the doctrine of the conservation of energy, but perhaps this would be reading into his words more

than is justified by the state of his speculations at the time, because, throughout his paper he uses the words "heat" (*chaleur*) and "caloric" (*calorique*) interchangeably.

In the more significant part of his paper, Carnot discussed in detail the changes occurring when the working substance is carried through a complete cycle of transformations, as follows:

Let us consider an elastic fluid, such as atmospheric air confined in a cylinder that is provided with a movable partition or piston. . . . Also let there be two bodies, A and B, each of constant temperature, that of A being higher than that of B. Now imagine the following series of operations to be carried out:

1. Place the body A in contact with the wall of the chamber containing the air; we assume that it transmits heat easily. As a result of this contact, the air acquires the temperature of the body A.

2. The piston rises steadily. The body A is kept in contact with the (cylinder containing the) air, whereby the air is maintained at a constant temperature during its expansion. The body A supplies the heat (calorique) necessary to keep the temperature constant.

3. Now the body A is removed, and the air is no longer in contact with a body that can supply it heat; however, the piston continues to advance. The air is rarefied, without acquiring more heat, and its temperature falls. We will assume that it falls to that of the body B; at this point the piston comes to rest.

4. Now place the air (chamber) in contact with the body B; the air is compressed by pushing the piston down. However, it now remains at a constant temperature, because it is in contact with the body B to which it gives up its heat.

5. Now the body B is removed, and the air is still further compressed, which produces a rise in temperature because it is now isolated. The compression is continued until the temperature of the air reaches that of the body A.

6. Now the air is again placed in contact with the body A, and the piston returns to the position previously reached under Operation 2.

7. The step described under 3 is repeated, and the other steps follow in the succession: 4,5,6, 3,4,5,6, 3,4,5,6, etc.

During these various operations, the piston is subjected to a greater or less pressure by the inclosed air; the elastic force of this air varies partly because of changes in volume, and partly because of variations in temperature; but it should be observed that for equal volumes, *i.e.*, for similar positions of the piston, the temperature is higher during a movement of expansion than when the movement is one of compression. Hence, during the former, the elastic force of the air is greater, and thus the force resulting from the expansion is larger, than that employed in compression. Hence, there is a surplus of motive force, which may be employed as desired. The air has served as the working substance; it has been used in the most advantageous way possible, because no unemployed restoration of equilibrium has taken place.

This series of transformations constitutes what is known as Carnot's Cycle. As here used, a "cycle" means a chain of operations to which a given quantity of a substance is subjected, so as to return entirely to its initial state. It must be remembered that Carnot was not reasoning in accordance with the principle of the conservation of energy. Heat measurements, always difficult, were far cruder in his time than they are now, and he knew of no reason for not thinking that the amount of heat given out by an engine is the same as that which it has received. It was not until long after Carnot's time that experiments were performed which proved definitely that an engine does not give out as much heat as it receives. When a theoretical working substance that has ideal characteristics is carried through a cycle and returned identically to its initial condition, it is unnecessary to consider changes in its intrinsic energy, but with any actual working substance this is not the case. Nevertheless, Carnot was able to show that a "reversible" engine, working between two given temperatures, would have the greatest efficiency possible; hence, greater than that of any real engine, which, of course, is not reversible. He proved that the efficiency of this idealized engine depends only on the temperatures between which it works, *i. e.*, on the difference between the temperature of the source (T_1), and that of the condenser (T_2). Thus, the efficiency is given by $E = (T_1 - T_2)/T_1$.

In 1854 the German physicist Clausius showed that Carnot's conclusions

based on the idea of the reversible cycle, were still applicable and useful, although they had been conceived in ignorance of the true nature of heat. Only slight modifications were necessary to adapt them to the newer dynamical theories, and thus they became important and permanent features in the science of thermodynamics. He pointed out that Carnot was the first to observe that when mechanical work results from a thermal process, heat passes from a hot to a cold body—and, conversely, heat can be made to pass from a colder to a hotter body by the expenditure of mechanical work. Clausius then carried the reasoning a step further and stated that "heat can not, of itself, pass from a colder to a hotter body," a generalization known as the Second Law of Thermodynamics.

In the light of modern thermodynamic theories, Carnot's investigations seem exceedingly simple, but their influence has shown that they had the qualities of inspiration. He not only denied the possibility of perpetual motion, but in suggesting a new method of analysis, he contributed incalculably to the theoretical and practical advances made during the latter half of the nineteenth century. Neither he nor any of his contemporaries could have foreseen the wide application of the principles which he enunciated. Innumerable investigations based on his pioneering work have shown that the processes of the entire physical universe involve the evolution or the absorption of heat. In its scope, the second law stands as one of the greatest generalizations of all time. Willard Gibbs was able to show that it is involved in every chemical reaction. Biologists have found it to be a controlling factor in both the physical and the chemical processes that distinguish living from dead matter. In the words of a modern physicist, "it must be regarded as one of the most firmly established of scientific facts."

The hundred years that have elapsed since Carnot's labors came to an end have witnessed to an unparalleled degree the manner in which one's work may live on after he is gone. Recalling once more that his conclusions were based on an erroneous doctrine concerning the nature of heat, and then surveying the practical developments that have grown out of his investigations to enrich the century and all future time, we can not deny him the credit due to a real pioneer. He opened up a region of permanent and ever-increasing value to the human race. It is inconceivable that later centuries will not see even wider applications of the principles and methods of investigation pointed out in 1824 by the young French engineer, Sadi Carnot.

ESSENTIALS OF THE GENERAL RELATIVITY THEORY

By Dr. MAX TALMEY

NEW YORK, N. Y.

ORIGIN AND CHARACTERIZATION OF THE GENERAL RELATIVITY THEORY

THE general relativity principle may be stated provisionally as follows: All systems in any kind of motion are equivalent for formulating the laws of nature. This means that all motion is relative in contradistinction to the special relativity principle,[1] according to which only uniform rectilinear motion is relative.

The basis of the general principle is the discovery that gravitation, *i.e.*, the tendency of a body toward any other body, and inertia, *i.e.*, the disposition of a body to resist a change of its state of motion, are but different manifestations of the same quality of matter. What led to this discovery is the circumstance, known but unheeded before the relativity theory, that the gravitational mass and inertial mass of a body are equal. From the equivalence of gravitation and inertia was deduced the principle of equivalence: Acceleration in one direction due to any force is equivalent in its effects to acceleration in the opposite direction due to gravitation. This principle is of great value in the investigation of the gravitational phenomena. Accelerated motion produced by a force at our command is examined in a laboratory. The results obtained can be applied to gravitation by reason of the equivalence principle. The general relativity theory turns upon this principle and is thus, on the whole, a new theory of gravitation. To gain an insight into it we have to know first how the general relativity principle of which the equivalence principle is a special form can be maintained against strong objections to it.

[1] Acquaintance with the special relativity theory is necessary to understand the general one. Those uninformed are referred to the writer's essay published in the SCIENTIFIC MONTHLY for January, 1932, under the title "Fundamentals of the Relativity Theory" and obtainable from the writer as a reprint.

VINDICATION OF THE GENERAL RELATIVITY PRINCIPLE

The phenomena of the jolt and of the centrifugal forces are apparently incompatible with the general relativity principle. The passengers in a train moving uniformly on a straight track may consider the train and everything in it to be at rest and the world outside of it to be in motion. But when the train suddenly changes its velocity or makes a turn, that is, when it undergoes an acceleration, the passengers receive a disagreeable jolt, a pull backwards, forwards or sideways, and objects in the train are thrown about. The passengers can then no longer deceive themselves by imagining the train to have remained at rest and its surroundings to have suddenly moved, thereby producing the disorder. Likewise rotary motion is recognizable by centrifugal phenomena. From the rapidly turned grinding-wheel spurts the water with which it is wetted. A pliable sphere rotating swiftly becomes flattened at the poles. The phenomena of the jolt and centrifugence consequent upon acceleration and rotation indicate non-uniform motion and identify the system where it is observed. Their cause can lie only in this system and nowhere else. This marks non-uniform motion as absolute

and furnishes a strong argument against the general principle.

But there is a more potent counter-argument. Suppose the train, the grinding-wheel, the pliable sphere remain at rest and the universe about them undergoes an acceleration. Are we then sure that objects in the train would not be shaken, the water not spurt from the wheel, the sphere not become oblate? The possibility of these phenomena of the jolt and centrifugence occurring under the assumed condition can not be excluded. Hence they are not sufficient to mark non-uniform motion as absolute. Their cause may be in the universe around the system where they are observed; they would appear if the system remained at rest and the universe were accelerated or revolved around it. The phenomena of night and day justify this reasoning. They may be due either to the earth rotating against a stationary firmament or to the firmament revolving around the stationary earth. The second view was the accepted one until Copernicus replaced it by the first one. Non-uniform motion is therefore relative as postulated by the general principle.

Equality of Gravitational Mass and Inertial Mass

The general relativity principle thus rests first upon the assumption that the masses of the universe exert a force upon any system. Such a ubiquitous force in nature is gravitation. Newton recognized it and established its law: Any two bodies tend toward each other with a force equal to the product of their masses divided by the square of their distance. He conceived gravitation and other forces to act across empty space without intermedium. Modern physics does not acknowledge this "action at a distance" but assumes that a body imparts to the space about it certain qualities by means of which it influences other bodies.[2] This altered state of the space is called a field. Its intensity diminishes with the distance and finally vanishes. The sun's gravitational field reaches until the remotest planet.

The second factor necessary to uphold the general principle is the equivalence of an accelerating force to gravitation acting in the opposite direction (equivalence principle). The observable effects are the same in both cases. An accelerated system is therefore replaceable by a small part of a gravitational field. This is proved through the close connection between gravitational mass and inertial mass.

All bodies in a vacuum fall to the earth with the same acceleration designated by the letter g. It follows from this that the gravitational mass (m) and inertial mass (m_1) of a body are equal. The former is the ratio between the weight[3] of the body and the gravitational acceleration: $m = W/g$. The inertial mass is the ratio between any force and the acceleration it produces: $m_1 = F/a$. We use the weight as the accelerating force, that is, we let the body fall in a vacuum, then we obtain: $m_1 = W/a$. Since all bodies fall with the acceleration g, the factor a in the last equation is to be replaced by g;

[2] These qualities are unknown and nowise explained by being designated as "space curvature." For this term is meaningless. (See below.)

[3] Weight is the pressure exerted by a body on something under it which prevents it from falling. It must not be confounded with gravitational mass. Weight and gravitational acceleration vary with the place on the earth, but gravitational mass, the ratio between the former and the latter, does not. That ratio in a body weighing one kilogram in Paris is 0.10195 everywhere on the earth. The equality of gravitational mass and inertial mass can not be inferred solely from the circumstance that they are always proportional. Two things which are always proportional need not be equal at all. Weight and width of a plate are always proportional, yet they can not be designated as being equal.

hence we obtain: $m_i = W/g = m$. The law of the equality of gravitational mass and inertial mass is thus proved. This universal law, as can easily be shown, is the reason why all bodies fall equally fast.

The equality of gravitational mass and inertial mass was known long before the relativity theory, but was considered as something accidental and unimportant. When its vast significance and the close connection between gravitation and inertia as different manifestations of the same quality of matter were discovered, the general theory developed. The bearing of this discovery upon the theory is elucidated through the following illustration.

Equivalence of an Accelerated System to a Small Part of a Gravitational Field Acting in the Opposite Direction

The room of a physicist is transferred to the interstellar space, where there is no gravitation. Objects exert here no pressure on his hand and remain floating in any spot where he lets them loose. A thing thrown towards one of the six walls moves with steady velocity and remains on it at the point toward which it was directed. A cord attached to the ceiling is not stretched by a ball fastened to its other end. The physicist, knowing that he is in a space free from gravitation, does not wonder at these phenomena, since they are characteristic of such a space.

A mysterious being begins to pull the room upwards with steady force by a rope attached to the roof. An observer outside of the room sees it now flying upwards with continually growing speed. For a steady force produces acceleration. The physicist, however, is not aware of this motion because he participates in it. But he notices a sudden change in the behavior of the objects in the room. They have weight and fall to the floor when let loose, all with the same acceleration. The cord attached to the ceiling is stretched by the ball.

Puzzled at this sudden change he looks about for its cause and discovers the rope. Now he believes to have found an explanation. A heavenly body has appeared below the room, and the latter is now in the body's gravitational field, held in position through the rope by some power above. On second consideration, however, he finds that there is also another explanation. A power above has suddenly begun to pull the room upwards. This accounts for the change of the phenomena.

Each explanation is fully adequate. It is impossible to decide whether the room is at rest in a gravitational field acting downwards or under the influence of an accelerating force directed upwards. This proves logically that an accelerated system and a small part[4] of a gravitational field acting in the opposite direction are equivalent in their effects and that accelerated motion is relative.

This proof rests upon the law of the equality of gravitational mass and inertial mass, due to which all bodies fall equally fast in a gravitational field. In our imaginary experiment all objects approach the floor with the same acceleration because they remain in their position and the floor is pulled towards them. If bodies did not fall equally fast in a gravitational field, that motion of the objects could be explained only by a pull of the room upwards but not by an attraction of the objects downwards.

[4] The lines of motion of objects at different places are strictly parallel in an accelerated system, but are radial, that is, converging towards the center of gravitation, in a gravitational field. For this reason a large extent of the latter can not be equated to the former. In a small part of a gravitational field, however, those lines may be considered as being parallel.

The ball on the cord resists the accelerating pull upwards, thereby stretching the cord; the ball's inertial mass measures the tension of the cord. Or the ball tends toward the floor owing to gravitation, thereby stretching the cord; the ball's gravitational mass measures the tension of the cord. The two measurements determine the same effect. This illustration shows the importance of the law of the equality of gravitational mass and inertial mass in the study of gravitation. The effects of acceleration produced by a force at our command are examined and the results obtained are applied for determining the qualities of a gravitational field. Herein lies the physical significance of that law.

Determination of the Qualities of a Gravitational Field

The space and time factors of a process in a system may be given. They can then be determined, in a purely mathematical way, for an observer in another system which is in accelerated motion relative to the first system. By reason of the equivalence principle the second system is replaceable by a gravitational field. The qualities of the latter can thus be established mathematically. The following example makes this clear. The path of a body moving through a Galilean or inertial system, *i.e.*, one free from gravitation, is a straight line. What shape has it for an observer in a gravitational field? We return to our imaginary experiment. A bullet shot off in the interstellar space enters the physicist's room through a vertical wall and flies out through the opposite wall. For an observer outside of the room the bullet's path is a straight line throughout. For the physicist, however, it is a straight horizontal line when the room is at rest, a straight oblique line when the room moves uniformly upwards, and a curved line, a parabola, when the room is in accelerated motion upwards. In the third case we may consider the room to be in a gravitational field. A quality of the latter is thus determined: what is a straight line in a Galilean system is a curved line in a gravitational field.

This gives us an idea of the mathematical complications in the study of gravitation. In an accelerated system or a gravitational field we can not construct a Cartesian coordinate frame of straight lines. The straight line loses its meaning there. The Euclidean geometry, being based upon the conception of the straight line, becomes inapplicable in an accelerated system, necessitating the use of another highly intricate geometry. Still more difficult is the mathematics required for systems in rotation, which is also a form of acceleration.

According to the special relativity theory a tangential length on a rotating disc is shortened, more when it is nearer the periphery than when it is nearer the center, while a radial length has the same value as when the disc is at rest. A clock nearer the periphery has on the rotating disc a slower rate than an equal clock nearer the center. The comparison of lengths of space and the correlation of intervals of time are therefore impossible in a rotating system. A length and an interval are here indeterminable, since they vary from place to place. In a rotating or an accelerated system, as can be shown, a square can not be constructed, the ratio between the periphery and diameter of a circle is not the well-known number π, and the Pythagorean axiom does not hold true. This means that the Euclidean geometry is useless in an accelerated system. To describe here the physical processes a method is needed in which the values of lengths and intervals can be dispensed with. Such a method is given through Gaussian coordinates.

A Gaussian system of coordinates consists of two series of lines curved arbitrarily, the lines of one series not

intersecting each other but intersecting those of the other series. Each line is represented by a number. A point is defined as the intersection of two curves and is thus determined by two numbers. This refers to a plane surface, *i.e.*, to a continuum of two variables. But the same method is applicable also to a continuum of more than two variables. The continuum figuring in physics has four variables, three relating to space and one to time. A point in it is determined by four definite arbitrary numbers which are its four Gaussian coordinates. These offer the advantage that they indicate coincidences of points and thus furnish for physical research a determinative factor which is independent of the system where the investigation takes place. A coincidence of two or more points is the only observable reality remaining the same in all systems, in one influenced by gravitation the same as in one free from it. In our space-time continuum a coincidence of points is given when they have in common one set of four Gaussian coordinates.

We see now that the previous enunciation of the general principle is inadequate. The term "system" used there and the term "motion" everywhere imply straight lines, lengths and intervals. These concepts are indeterminable in a gravitational field. Hence they should not be used in enunciating the principle. It becomes exact when stated as follows: "All Gaussian coordinate systems are equivalent for formulating the laws of nature."

The Gaussian coordinates of the space-time continuum are brought into relation to measurements of lengths and intervals through a roundabout mathematical way. It can be pursued only by the most able mathematicians. It leads to a general law of gravitation. This new law differs from the Newtonian law and embraces it in the first approximation, that is, when the mathematical calculation is not carried too far. Herein lies a notable confirmation of the general relativity theory.

Misleading Phrases of, and Fanciful Ideas Injected into, the Relativity Theory

A great authority remarked that "a single man, Einstein, destroyed confidence in the evidence of the Euclidean geometry," and another one stated that "the whole edifice of the Euclidean geometry is tottering." To such inadvertent utterances is due the widespread notion that Euclidean geometry has been overthrown. This is a fallacy. That geometry is not invalidated in the least, but only inapplicable in a gravitational field. A length is here unmeasurable and a straight line untestable. A light ray, the only standard for a straight line, is bent in a gravitational field. This follows from our imaginary experiment. The bullet shot through the accelerated room may be replaced by a light ray. The latter describes a parabola just as the former does. A non-Euclidean geometry, *i.e.*, one not founded upon the conception of the straight line, is therefore needed in the study of gravitational fields. This nowise implies invalidity of the Euclidean geometry.

The quality of curvature was ascribed to the space in a gravitational field in order to explain why a light ray is bent and consequently Euclidean geometry inadequate in such a system. This idea was an unnecessary and infelicitous appendage to the relativity theory. It has caused great confusion and has involved the theory in mystery. The current phrase, "space is curved," is meaningless. Moreover, it has not been disproved that there is in the universe vastly more space free from gravitation than space influenced by it. A light ray has not been proved to be curved in the former. Now the only criterion for "space curvature" is the bending of a

light ray. Hence space is vastly more often "straight" than "curved," whatever this may mean. The deviation of a light ray in a gravitational field is readily explained without "space curvature."

The deflection of light through gravitation does not justify the claim that a light ray traveling through the universe may describe a circle and return to its origin, and the antipodes on the earth may see the opposite sides of a star at the same time. This could be the case only if all the innumerable gravitational fields traversed by a light ray deflected it invariably to the same side. Such a contingency is unthinkable. A ray will rather pass as many fields bending it to one side as fields deflecting it to another or to the opposite side. It will, therefore, not describe a circle but an irregularly curved line whose average course is straight. The notion that the path of a light ray in the universe may be a complete circle belongs to the fanciful ideas injected into the relativity theory.[5]

Verification of the Relativity Theory

Both the special relativity theory, treated elsewhere by the writer (see note No. 1), and the general one are confirmed by experience. Deductions from the former are corroborated by two astronomical observations, namely, the apparent displacement of the stars or aberration and the Doppler principle and by various electromagnetic and optical experiments. Similarly, inferences from the general theory are verified by experience, by observation. There are three such inferences, to wit, the deviation of light passing the sun's gravitational field, the anomaly of the planet Mercury, and the displacement of the spectral lines in the spectrum of sidereal light. It would unduly extend this essay to discuss all these interesting subjects at full length. They are enlarged upon and illustrated in a book, to be published later, of which this essay is an extract. In the latter it must suffice merely to mention all observational and experimental facts which support the special relativity theory and the general one.[6]

Concluding Remark

It is due largely to the use of the terms "fourth dimension" and "space curvature," mystical and meaningless in ordinary language, and to the injection of fanciful ideas into the relativity theory that it is so little understood. All these perplexities can be avoided in interpreting the theory. If it is not obscured and mystified through them, it can be made quite intelligible to the educated layman.

[5] See the writer's article, "Fanciful Ideas Injected into the Relativity Theory" (pp. 39–40), published in the *Am. Math. Monthly* for January, 1932, and obtainable from him as a reprint.

[6] The unitary field theory has but little connection with the general relativity theory proper and is therefore out of the scope of this essay. The union of gravitation and electromagnetism forms the essence of the field theory but hardly comes into consideration in the general relativity theory. The notion of curvature infused into the conception of the "space-time continuum" has mystified and obscured this term. Yet there is nothing mysterious and difficult about it. Space and time in the new physics are united in a "space-time continuum." This merely means that both must be considered in describing a physical event so that it is fully determined only when the time variable is given together with the three space variables. Time is distinct from space, even in physics, and is not intermixed with it in any mysterious manner. Feuilletonists tell us that gravitation has been replaced by "space-time curving around the sun." It is such meaningless abracadabra that has produced the prevailing confusion about the conception of the "space-time continuum" in physics.

INTERNATIONAL RADIO TUNING AT LONG RANGE

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ALTHOUGH radio broadcasting is only in its first decade of service, yet it is now well known to the general listener that a radio receiving instrument can not deliver speech or music until it has been tuned to the particular radio transmitting station that is "putting its program on the air." This means that each and every transmitting station has its allotted tone or electrical pitch, on which it is licensed to reach its listeners in the far beyond. Since there are many radio stations operating simultaneously, these precious radio channels through the ether lie close together in successive orders of pitch, and each station must keep faithfully to its assigned tone. It is as though each one of the 88 keys of a piano could somehow be used for audible signalling by an operator, independently of and without confusion from all the other 87. If, however, the pitch of his note altered seriously during operation, say by flatting, he would probably be brought into interference with the operator working on the note next below. The electrical pitch of a radio station is so high that it far exceeds the limits of audibility; yet it must not be allowed to flatten or sharpen beyond a very small range or it will interfere with the next neighboring pitch of some other station, which may happen to be far away. Nothing is more annoying to a radio sending station that is keeping true pitch than to find some other station invading its channel and confusing its program. To keep the radio peace, radio pitch must first be kept.

To facilitate the maintenance of the pitch or "carrier-wave frequency" of a radio station, electrical instruments, called frequency meters, may be used, with the aid of which the station operator can assure himself from time to time that he is on tune. Occasionally, of course, such an instrument may become defective without the operator becoming aware of it, and then it is a case of "Quis custodiet ipsos custodes?" As a safeguard, it is not unusual for a standardizing electrical laboratory, such as the National Bureau of Standards at Washington, D. C., to broadcast, at certain announced times, a carefully tested and specified electrical pitch, so that stations prepared for the event may compare their frequency meters with the signal. In that way, small defects in the indications of such meters may be noted, far away from the station sending out standard pitch.

There is an international society called, in the English language, "The International Union of Scientific Radio"; but more generally known in Europe under its French title, "Union Radio-Scientifique Internationale," usually referred to by its initials URSI. The URSI investigates the science of radio communication, and has appointed several international standing committees to study different aspects of this wonderful subject. Committee No. 1, on "Standards," is interested in radio standards generally, and among them, in standard frequencies, their emission, measurement and intercomparison. This committee has recently issued a very interesting report on some frequency-emission tests made last June at the British National Physical Laboratory (usually abbreviated to NPL)—in Teddington on the Thames near London.

At the NPL, there was a specially constructed tuning fork, electrically driven, so as to be kept in action steadily for a long period, under carefully controlled air pressure and temperature. The pitch, or vibration frequency, of this fork was maintained very nearly constant at one thousand (1,000.00) to-and-fro vibrations, or cycles, per second. As this is a readily audible frequency in sound waves, and C^2, the note C on the second line above the treble clef, corresponds, on the scientific musical scale, to 1,024 cycles per second, the fork would emit a musical note of pitch slightly below C^2.

Many electric frequency meters depend upon building up successive octaves or multiples on a basic frequency of 1,000; so that if this basic frequency can be accurately established, correct radio frequencies of far higher pitch can be more readily assured. The object of the broadcasting tests was, therefore, to enable as many European stations as might be interested, to compare simultaneously their local 1,000-pitch forks with the standard fork in the laboratory at Teddington.

At the previously announced hour, which was actually midnight Greenwich civil time, *i.e.*, world time, the standard fork was connected, electrically, by underground wires to Broadcasting House, London, whence the standard frequency of 1,000 cycles per second was relayed on, again by wire, to a radio station in central England, at Daventry, about 125 kilometers northwest of Teddington. Daventry has Roman remains that show it must have been an established settlement in the days of that empire. It was also the headquarters of Charles I, in 1645, just before his defeat at the battle of Naseby. The Daventry radio station employs a carrier-wave frequency of 193,000 cycles per second. Since the highest pitch audible to the human ear is about 16,000 cycles per second, it is evident that the Daventry pure electrical note, if picked up by a receiving loud speaker, would produce no sound; but by superposing on it the "modulation frequency" of 1,000, so as to cause the high electric pitch to wax and wane 1,000 times per second, suitably tuned and connected loud speakers all over Europe could be made to emit the note of nearly C^2 pitch.

Observations of the Daventry 1,000 modulation note were made in Berlin, Paris, Warsaw, Italy, Denmark and Sweden, besides in various English stations, according to the URSI report. The frequencies measured at these foreign stations, in terms of their own standards, as subsequently reported by them, varied between the limits of 1,000.0002 and 999.9997 cycles per second, a total range of 0.0005, or one part in two millions. The report indicates that, judging from the experience of this and similar tests, it should be feasible to determine and maintain a standard frequency, of this order, to a precision of one part in ten millions. This degree of precision, while very satisfactory from a scientific point of view, is considerably in excess of practical radio requirements at the present time.

The NPL standard fork had itself been measured and adjusted in its frequency, by daily astronomical time signals, and a first-class standard laboratory clock.

Two inferences disclose themselves from a perusal of the report; one physical and the other philosophical:—namely, first, that these frequencies of carrier wave and of modulation, emitted from the Daventry radio station in various directions, remained constant up to a range of 1,000 kilometers, to within a measured precision of at least one per million. This constant-frequency property of traveling radio waves is generally accepted; but, possibly, had not previously been submitted to so severe a test. Second, during the continuation of the tests, which actually

occupied only a few minutes, the effect of the various wire and wireless connections was such that the standard fork in the NPL laboratory was virtually transported into each and all of the various receiving laboratories—in the sense that the actions there locally produced were equivalent to those that might have been produced, if the fork had been instantly transported across the intervening surface of the globe.

So long as the various nations are able to maintain their standard radio frequencies to within a few parts in ten millions, it is evident that peace and amity may be expected to enfold them. Every radio link is a bond of good-will. As radio science develops, under the auspices of the URSI, it may be hopefully anticipated that the same precise exchange of frequencies will gradually extend from one to all the continents.

SALIENT THEOREMS OF THE THEORY OF GROUPS AND THEIR HISTORY

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AMONG the 1932 theorems relating to the foundations of group theory is the one which asserts that the quaternion group is the only finite non-commutative group containing a set of generating elements which includes the product of every pair of distinct elements thereof without involving all the elements of the group generated by it. This theorem exhibits, in particular, the extent of the probable misunderstanding as regards finite non-commutative groups resulting from the common statement that one of the conditions that a set of operators constitutes a group is that it involves the product of every pair thereof. A rule equivalent to the formula that the number of pairs of n distinct elements is $n(n-1)/2$ was given by Ammonius, the founder of the new Platonic school, but it has often been erroneously credited to Boethius, who lived about 275 years later.[1]

It is a somewhat singular fact that such an elementary theorem has not yet been found in the earlier literature. In particular, it does not appear in Euclid's "Elements," which includes so many of the results found by earlier investigators. Such negative results throw much light on the history of the intellectual development of the human race and on the weak points of the mathematics of early civilizations. While no expression for the number of pairs that can be formed with n distinct elements seems to appear in the mathematical literature preceding the Christian era there are many evidences therein of the consideration of pairs. For instance, Euclid's "Elements" contain a rule which is equivalent to the formula $4ab+(a-b)^2=(a+b)^2$, where a and b represent positive numbers and a is assumed to exceed b.

It has not been sufficiently emphasized in the histories of mathematics that the Greek geometric interpretation of the rule which is equivalent to the formula $(a-b)^2=a^2-2ab+b^2$ is of fundamental importance in the history of negative numbers, since it gave rise to the rule that a subtracted number multiplied by a subtracted number gives an added number, and a subtracted number multiplied by an added number gives a subtracted number. This rule is found in the "Arithmetica" of Diophantus and gave rise later to the modern rules relating to the multiplication

[1] *Cf.* D. E. Smith, "History of Mathematics," Vol. 2 (1925), page 524.

of positive and negative numbers. The addition and the subtraction of positive and negative numbers were clearly understood long before the operations of multiplication and division relating thereto were explained in a satisfactory manner.

The development of the theory of negative numbers was doubtless influenced by the observation that they may represent the inverses of the corresponding positive numbers such as debts when the positive numbers represent credits, or distances in the opposite direction from those represented by the positive numbers. The available evidences seem to point to the fact that the most potent influence in the introduction of negative numbers was the development of a calculus of binomials on the part of the ancient Greeks, especially in the form of differences between two positive numbers. This calculus appears in Euclid's "Elements," and it became widely and favorably known as a result thereof. The development of negative numbers is an important element of the history of group theory, since the totality of numbers could not be regarded as a group with respect to addition until negative numbers and a zero were regarded as a part of their domain.

An important element of the definition of a group which has not received much attention on the part of writers on this subject is the fact that only two elements are supposed to be combined at the same time therein. If more than two elements of a group are combined it is assumed that the result is obtained by combining successively two of them or by combining the result thus obtained with another element of the set. Such an operation as combining n elements and also multiplying their ordinary product by n is not considered in group theory for the cases when $n > 2$. Hence it results that the question of pairs of elements is fundamental in this subject even if the number of such pairs is of secondary importance therein.

The fundamental theorem of algebra is equivalent to the statement that an algebraic equation of degree n has exactly n roots. In group theory only binomial equations of the form $x^n - 1 = 0$ are considered and such an equation has exactly n roots within a group of order n. There is only one such group when and only when n is not divisible by the square of a prime number and also none of its prime factors diminished by unity is divisible by another such factor. In all other cases it has more than n roots within the groups of order n. It is especially important to note in this connection that whenever n divides the order of a group, then this equation has always a multiple of n roots within this group, according to a theorem proved by G. Frobenius in 1895 and known by his name. It is not always possible to construct a group for which there exists an arbitrary multiple of such roots.

The development of group theory during the last forty years is analogous to the development of entire mathematics during the early part of the nineteenth century. The enumeration of all the possible groups of a given order and the recent determination of all the orders for which a given small number of groups exist are comparable with the work of the combinatorial school of Germany founded by C. F. Hindenburg (1741–1808), while the theory of linear groups and group representation may be compared with the developments of A. L. Cauchy and N. H. Abel relating to the convergence of infinite series. The former led to some useful results, but the complexity encountered turned investigators into other fields. Elegance and simplicity of results have always exerted a powerful influence on the mathematical investigator. The almost 300 distinct groups of order 64, for instance, can scarcely be supposed to

appeal to those who wish to use group theory as a tool for investigating other subjects. On the other hand, the theory of the representation of groups has recently been successfully employed in physics by H. Weyl, E. Wigner, B. L. van der Waerden and others, and promises to become a substantial part of mathematical physics, even if it has been referred to by some of the workers in this field as a pest which should be gradually eliminated.

E. Galois and L. Sylow contributed towards the development of a salient theorem which is now commonly known by the name of the latter and asserts that every group of finite order contains at least one subgroup whose order is the highest power of a prime number which divides the order of the group. The former of these two investigators died before reaching the age of 21 and is the only man who secured at such an early age a position among the 25 leading mathematicians of all times. On the contrary, the latter developed slowly and did not secure a university professorship until he was about 66 years old. E. Galois stated without proof that if the order of a group is divisible by a prime number, then it contains a subgroup whose order is this prime. A proof of this theorem was published by A. L. Cauchy in his noted "Exercises" (Vol. 3 (1844), page 250). The article in which Sylow's theorem first appeared (1872) contains also the theorem that a group whose order is of the form p^m, p being a prime number, contains an invariant subgroup of order p and hence it contains at least $p-1$ invariant operators of this order. This theorem has been very fruitful.

It is not our object to give here an extensive list of salient theorems of group theory, since many of them involve points which are of little interest to the general reader. A list of 217 such theorems appears in A. Speiser's "Theorie der Gruppen von endlicher Ordnung," second edition, 1927. Our object is to give here a few instances of the nature of the questions considered in this field of mathematical activity. This may be justified by the fact that a growing general interest in this field may be supposed to result from the recent uses made of group theory in mathematical physics by H. Weyl and others, and that this subject has recently been recognized as belonging to elementary mathematics in the second part (1932) of Vol. 1, "Enciclopedia delle matematiche elementari." This recognition is the more interesting, since the Italians have made comparatively few contributions to this field and give generous references to contributions along this line by American writers. In no other field are such contributions more outstanding.

The difficulties of the student of modern mathematics are greatly increased by the lack of uniformity in the use of terms and by the liberty exercised by some writers of wide reputation to deviate from well-established usage. As an illustration we cite here H. Weber's use of the term metacyclic for solvable. If writers who have not yet an established reputation make such digressions it is commonly regarded as an error, but writers of renown are usually granted by the mathematical public licenses which unduly tax the younger workers in the same fields. H. Poincaré could say without refutation "The theory of groups is, so to say, entire mathematics divested of its matter and reduced to pure form" ("Acta Mathematica," Vol. 38, 1921, p. 145). A somewhat more critical attitude would probably tend to lessen the burden of those to whom future progress will be confided. The modern formal mathematics is obviously not now confined to group theory, as this term is commonly understood.

The concept of cyclic group is as old as that of the circle, and hence it is pre-

historic. The fact that the number of the hours of the day may be regarded as a modulus with respect to the addition of time, and hence that the numbers of these hours constitute a cyclic group with respect to addition, was realized by the ancient Babylonians and the ancient Egyptians, who employed early a day of 24 hours. Sometimes two moduli were used for the day and the night respectively, and various other divisions were employed. In fact, in some countries two moduli, each equal to 12, are still in use. The fact that all the vectors of the plane, and also those of space, constitute a group with respect to addition enters into the experience of our daily life and is fundamental in elementary geometry. While the concept of cyclic group is very ancient, the properties of this group, such as the number of its generators, now known as the totient or the Euler ϕ-function of its order, do not seem to have been explicitly noted before the eighteenth century.

The concept of non-cyclic group is more difficult to trace far into the past literature, and comparatively little progress has been made along this line. The simplest example of such a group is the four-group, which appears explicitly as a permutation group in the works of J. L. Lagrange, but is probably much older. It contains a set of three generating elements, each of order 2, which includes the product of every distinct pair of them, and hence it also illustrates the danger of misunderstanding resulting from the statement that a set of permutations constitutes a group if it involves the product of every pair thereof. Josiah Royce called attention to the fact that a certain set of three logical entities of the Boolian calculus define this group, which is also known as the axial group, or the anharmonic ratio group.[2]

Arithmetic and geometric series are among the most ancient concepts of mathematics, as they appear already in the ancient Egyptian mathematical papyrus written by Ahmes. It has recently been noted that an arithmetic progression extended infinitely in both directions constitutes a group when and only when it involves the sum of at least one pair of its terms. Similarly, a geometric progression thus extended constitutes a group if and only if it involves the product of at least one pair of its terms. The very elementary character of these facts would seem to justify the effort to find earlier explicit statements thereof, but in the history of science as well as in the development of science it is observation and experiment that give a definite yes or a definite no to our hypotheses. While group theory is a comparatively young subject its history presents many unsettled questions and points to the almost insurmountable difficulties involved in securing a satisfactory general history of the entire field of mathematics. The efforts along this line are, however, laudable, since they tend to exhibit inspiring advances which appear to be of permanent value.

[2] *Cf. Journal of Philosophy, Psychology, and Scientific Methods*, Vol. 10, p. 619, 1913.

ENEMIES OF SOCIETY[1]

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THE history of our race may be instructively considered in terms of a gradually expanding freedom. Slowly and painfully, in the course of many centuries of struggle, we have cast off the chains of slavery, and to a great degree we have overwhelmed the tyranny of government. Within reasonable limits we have achieved liberty of speech and of printing. But these were achievements in civil or political liberation. By applying knowledge of physical and chemical sciences we have further freed ourselves from exacting restrictions. Thus the limitations which seasonal changes impose we have escaped by devices for heating and refrigeration; we have pushed far away the confines of space and time by rapid transportation of goods and people on land and in the air, and by the flashing of information in seconds from the remotest corners of the earth; by means of artificial illumination we have abolished the terrors of darkness; and through the methods of orderly research we have learned the nature of mysterious events in the heavens and on the earth that from earliest times have held the minds of men in fear of dire disasters.

As members of the medical profession we are justified in regarding with pride the rôle which our profession has played in the process of setting humanity free. In performing this service to humanity I would emphasize the point that medical ods of inquiry that have been used by investigators have used the same meth-investigators in physics and chemistry. They have studied biological phenomena as they occur in nature, they have drawn inferences concerning them, they have tested these inferences by experiment, and thus by patient, ingenious and critical study they have learned the regular sequence of events, "the rules of the game." And just as this scientific method has transformed the physical world, giving us means of electrical heating and cooling, the automobile, the airplane, the telephone, wireless communication and animated speaking records, so likewise the method has helped to transform the social world by its conquest of disease. Let us consider for a few moments the thraldom of plagues and pestilences under which our ancestors suffered, and we shall be better able to estimate the momentous services of medicine in establishing the relative security of our present civilization.

Again and again, after devastating Asia and Africa, the bubonic plague swept into Europe. Many vivid descriptions of the havoc it wrought have come down to us. One epidemic in the fourteenth century is said to have caused the death of over 60 millions of human beings. In that epidemic Genoa lost 40,000, Naples 60,000, Siena 80,000 and Sicily and Apulia more than 500,000 inhabitants. The city of Trapani was completely depopulated—all died—and her silent walls and empty dwellings were alone left to tell the tale. The dead were dumped pell-mell into huge pits, hastily dug for the purpose, and putrefying bodies lay neglected everywhere in the houses and the streets. During later centuries scattered outbreaks of the plague in various European countries were accompanied by

[1] An address read at the annual meeting of the New York Academy of Medicine on November 3, 1932.

similar scenes. Pepys in his diary tells of what he saw at the "great pit of the churchyard at Aldgate" as one dead-cart after another brought its load, "sixteen or seventeen bodies, some wrapt in linen sheets, some in rugs, some little other than naked, or so loose that what covering they had fell from them in the shooting out of the cart"—"huddled together into the common grave—rich and poor together." "Now people fall as thick as the leaves in autumn when they are shaken by a mighty wind," reported Thomas Vincent, an eye witness. "Now there is dismal solitude in London streets. . . . Now shops are shut in, people rare and very few that walk about, and a deep silence in every place. . . . If any voice be heard it is the groans of dying persons breathing forth their last. . . . Never did so many husbands and wives die together; never did so many parents carry their children with them to the grave, and go together into the same house under earth who had lived together in the same house upon it. Now the nights are too short to bury the dead; the whole day, though at so great a length (it was August), is hardly sufficient to light the dead that fall thereon into their graves." The mysterious and appalling disaster wrought wide-spread demoralization among the people: some, overcome by terror, fled from their friends, their homes, their dearest relatives; others gave themselves up to the wildest debauchery—"eat, drink and be merry," they said, "for to-morrow we die." Such was the plague during hundreds of years of European history.

It should not be forgotten that the plague has not disappeared. An epidemic starting in China spread over the world in 1894, and without modern protective agencies would probably have attained medieval proportions. In India alone, during the year 1905, the number of recorded deaths from plague was more than 1,040,000. Two years later our own country was invaded, and serious conditions might have developed if stern measures had not been taken to protect our population. These measures, as you well know, were based on careful scientific studies which had revealed the natural sequence of events. It was proved that the bacillus pestis is spread among rats by fleas and can be transferred by these insects from rats to monkeys. The inference was clear. To protect men from these dangerous flea bites the rodent carriers of the fleas must be destroyed. Those were the rules of the disease as demonstrated by tested experience. Now, in accordance with these rules, rats are trapped and killed, rookeries and vermin-breeding hovels are torn down, and victims already infected are isolated, so that they shall not be the cause of further infection. Wherever it has been possible to apply the rules, seriously threatening epidemics of the plague have been stopped so that mankind is now largely freed from the terror of the Black Death.

May I be permitted to mention in some detail another extension of human freedom due to our profession—the growing freedom from the disease diphtheria. Death from this disease was formerly frightful both for the victim and for the attendants, because the membrane in the larynx commonly caused strangulation. Indeed, the Italian name for diphtheria was "garotillo," the strangler. Listen to Trousseau's classic description of the way in which diphtheria used to kill 50 per cent. of those attacked:

> The difficulty of respiration increases in severity. Every hour, or every two or three hours, a suffocative fit comes on. The suffocative attacks follow one another more rapidly and become more and more violent. From time to time the infant, in a state of excitement which it is impossible to describe, suddenly sits up, seizes the bed curtains and tears them with convulsive frenzy; he throws himself on the neck of his mother or on those

about him, embracing them and trying to clutch whatever he can as something to hold by. At other times it is against himself that he directs his impotent efforts, grasping violently the front of his neck, as if to tear out from it that which is suffocating him. The puffy, purple face and the haggard, sparkling eyes express the most painful anxiety and the most profound terror; the exhausted child then falls into a sort of stupor, during which respiration is difficult and hissing. The face and lips are pale, and the eyes sunken. At last, after a supreme effort to breathe, the agonies of death begin and the struggle ends.

Such pathetic and distressing scenes we have not witnessed for nearly four decades. By carefully conducted experiments on guinea pigs, rabbits, goats and horses, the rules of the disease were learned, *i.e.*, that it is caused by a bacterial toxin, that the body produces a defensive antitoxin, and that by use of an antitoxin developed artificially in the blood of the horse the natural defences of the patient can be promptly and overwhelmingly reinforced. By employing this tested knowledge—by obeying the natural rules which critical experience has discovered—the death rate was reduced in 19 of the largest cities of the world from about 80 per 100,000, in 1894, to 17, in 1907, a short period of 13 years. When antitoxin is used as soon as the disease can be diagnosed the mortality is almost nil. And now, best of all, by active immunization whole populations can be effectively protected from attacks.

I have not the time, and it is not necessary before this audience, to detail other triumphs of the application of scientific methods to medical problems. It will serve my present purpose, however, to refer to a few of them in a cursory survey.

By application of the experimental method the rules of surgical sepsis were learned and the rules for avoiding sepsis were discovered and developed. Thus was made possible the beneficent services of modern surgery—in the removal of tumors, the abolition of neuralgic and other pains, the repair of injured parts, the exclusion of dangerous infections.

By learning through experiments the rules of the diseases medical investigators have shown how yellow fever and typhoid fever, which formerly afflicted vast populations, can be controlled and rendered insignificant.

By learning the rules of the diseases the experimenters have been able to reduce the death rate of hydrophobia from about 14 per cent. of persons bitten to less than 1 per cent.; to reduce both the mortality and the damaging consequences of the epidemic form of cerebrospinal meningitis; to reduce the death rate from tuberculosis to about one fourth what it was fifty years ago.

By a long series of experimental inquiries the rules of the disease, diabetes, have been largely learned, and in accord with these rules there has been discovered within the past ten years a method of treatment which has freed hundreds of thousands of diabetic patients from the pangs of starvation, prolonged the life and usefulness of adult victims and given to diabetic children assurance of continued existence.

Through another series of experimental researches, the mode of dealing with anemia was suggested, and in consequence a certainly fatal human disorder, pernicious anemia, has been brought under control.

Many more examples might be given to show how medical and biological investigators, using the same general methods of inquiry as are used by chemical and physical investigators, have disclosed the secrets of natural processes and thereby have made for humanity if not a new heaven, at least a new earth. The lesson of these triumphs is clear. If we learn nature's rules, the regular and routine sequence of events, and then play the game of our relation to natural events in accordance with those rules, we can move onward to larger, more

complete control of these events. And just as we secure such control and use it, we leave uncertainty, we no longer see as through a glass darkly but face to face, and by such knowledge more and more are we made free. To medical investigators human society owes an incalculable debt of gratitude for relief from distressing pain, from the terrors and abominations of disease and from early death.

If you grant all that I have said up to this point, and I have tried to rest my case on well-authenticated facts, you can readily understand why it is that the training for the profession of medicine requires a longer time than the training for any other profession. The prospective physician, learning to understand the human body, is confronted with the most complicated system of coöperating parts that is to be found anywhere; he must learn the normal structure and workings of those parts singly and in relation to one another, for he needs that knowledge in order to have a basis for the recognition of disease. After he has met that reasonable requirement he must be educated in regard to all the more common diseases so that he can identify them, and he must become acquainted with the numerous and intricate rules of bodily order and disorder which he must later teach and enforce in order to maintain personal and social health; he must know the peculiar values of the varied forms of remedial agents and procedures so that he may apply the treatment most helpful to each patient; in emergencies he must be able to recognize promptly the existing conditions, for failure to do so may result in death. When, after at least six years of intensive professional study and one or two years of intensive observation and care of patients in hospitals, he is at the end of his formal training, he is ready to be a reliable servant of society in the treatment and prevention of disease among its members.

All these considerations are so familiar to this audience that I have hesitated to recite them to you. And yet if such stern and rigorous discipline is regarded by us as the prerequisite for certified expertness in medical practice, what shall we say of those who scorn the need for such discipline, who ridicule the evidence which painful human experience presents in overwhelming volume, who rush in as experts in the cure of disease when they have not learned the elements of the normal or the pathological processes with which they must deal? I submit that such persons are properly designated as enemies of society. I propose to consider with you some of their characteristics and to discuss the social dangers of their attempts to practice medicine.

In the first place, we must realize that our profession has undergone a long process of evolution. Magicians and medicine-men constituted the earliest professional class in primitive society. For thousands of years they made use of many varieties of incantations, charms, amulets, elixirs and decoctions, as well as prayers, music and the laying on of hands. Only gradually have rational medical knowledge and treatment risen out of this foggy morass of mysticism, and only during the past eighty years has the seal of experimental proof been placed on medical inferences. During all this recent history of the race, at every stage, representatives of the earlier fantastic and superstitious period of medical practice have appeared. At the time of Clowes, Paré, Vesalius and Linacre, in the sixteenth century, quackery was rampant, and was practiced, as a contemporary report has it, by "tinkers, tooth-drawers, peddlers, ostlers, carters, porters, horse-gelders and horse-leeches, idiots, apple-squiers, broom-men, bawds, witches, conjurers,

sooth-sayers and sow-gelders, rogues, rat-catchers, renegades and proctors of spittle houses." Two centuries later, when Monro, Boerhaave, the Hunters, Withering, Jenner and physicians of like character stood out as builders of the rising edifice of medicine, they were surrounded by successors of the primitive magicians—astrologers and holy healers, who practiced on the sick in the ancient manner, selling anodyne necklaces to pregnant women, providing "celestial beds" for the cure of sterility (at £50 per single occupation!), lauding the virtues of magnetic tractors, making fortunes from proprietary medicines (one of which was composed of "egg shells, garden-snails, swines' cresses, soap, burdock seeds, hips and haws"), and employing the ancient artifice, "laying on of hands."

Again, two centuries later, at the present time, we find the same elements present among those who profess to care for the sick. On the one hand are they who represent the growing forces of medical knowledge which, as I have reminded you, have mitigated or abolished great pandemic diseases and brought the blessings of surgical skill so that human society now lives in a new sense of security. On the other hand are the modern representatives of sourcerers, mystics, vendors of panaceas and artists in the magic touch. Practitioners of Christian Science, chiropractors and naturopaths are to be found on all sides, using the historical methods of faith cure and manipulation. What is the basis on which they rest their methods?

Christian Science denies the existence of disease. "Disease is illusion," wrote Mrs. Eddy. "Man is never sick, for Mind is not sick and matter cannot be." . . . "Disease is always induced by a false sense mentally entertained, not destroyed. Disease is an image of thought externalized." Thus with the dash of a pen-stroke the achievements of the medical profession in saving and protecting mankind from devastating pestilences is lightly dismissed as an absurdity.

"Chiropractic" is built on a slight modification of the ideas which originally supported osteopathy; now, because osteopathy has broadened its methods and requires more exacting standards than formerly, "chiropractic," with its brief preparation and low requirements, is usurping its place. According to chiropractic theory disease is due to partial displacement of vertebrae which pinch spinal nerves passing between them and which thereby interfere with the flow of vital energy to the body tissues. As B. J. Palmer, head of the original Palmer School of Chiropractic, testified in court, "Chiropractically speaking, disease is simply a register as to the amount or excess of current that an organ receives at the end of a nerve." For instance: "diarrhea shows too much force going to the bowels, particularly to the rectum. In constipation there isn't enough force going. It is simply a register of force at the same place in two different quantities, both being regulated by subluxation in the spine." . . . "Too much function or not enough function is the only classification you can put on disease" . . . "melancholia, not enough function, in the maniac too much" . . . "in the case of the kidneys, diabetes too much, Bright's disease not enough." "Do you recognize reflex action?" asked the lawyer. "Absolutely no," was Palmer's answer. "Do you recognize the sympathetic nervous system?" "No, we recognize only a direct nervous system and the direct flow of current." By manipulation the chiropractor is supposed to correct the malpositions of the vertebrae—not instantaneously, but by steps—and as the bones are gradually restored to their normal places the disease which they have caused is modified and finally disappears. Such are the ridiculous claims. And there are about 16,000 chiroprac-

tors in the United States supporting these claims—and incidentally themselves!

The naturopaths and their ilk, unlike the chiropractors, employ many healing agents, but rule out drugs and surgery. According to the leader of the sect, only the naturopath knows the right combination of these agents. They include *thalamotherapy,* treatment of disease by light through colored lenses that affects the viscera through the thalamus; *sysmotherapy,* treatment by means of vibrations which "equalize the circulation in the body"; *neuropathy,* simultaneous and intermittent manual pressure on one or more parts of the body to relieve nerves that are affected through muscular lesions, faulty nutrition or traumatic conditions; and *new field science,* removal of the cause of disease and the neutralization of toxic states by proper chemical combinations, as found in desiccated vegetation, herbs and cell salts. One naturopathic "cure" is known as the *Christos biological blood wash,* which consists of spraying water on various areas of the skin for some eight hours—really a prolonged shower bath!

The catalogue of the First National University of Naturopathy has this to say regarding entrance requirements, "Although a high school education is a great advantage in enabling the student to grasp the principles taught, this is not yet demanded." On completion of the course the student receives four diplomas, doctor of chiropractic, doctor of naturopathy, doctor of physiotherapy and master of physical culture. At another college, conducted in night courses, an insurance clerk was reported to be "professor of pathology," and among the candidates for the D.N. degree were a carpenter, a watchmaker, an ex-window washer, a telegraph messenger and a hod carrier. It is estimated that there are about 2,500 such healers in our cities.

All the representatives of these cults set themselves up as practitioners of the art of healing and declare that they cure all kinds of illness. But what basis have they of knowing a disease when it is present? Christian Scientists are not required to know anything of the structures and workings of the body, its changes in pathology or the symptoms and signs of disorder—indeed, their doctrine renders all such knowledge unnecessary. Socially dangerous and socially controllable infections, such as smallpox, typhoid fever, septic sore throat, do not exist. They are delusions—the mere "image of thought externalized." Is it safe for society to trust its welfare to persons who act in accord with such absurd ideas? Is it proper to look with equanimity on "healers" who consider dysentery or diphtheria *in an infant* as being "a false sense mentally entertained," and then proceed to treat the condition by prayer? Such spurious "healers," posing as experts, speaking with impressiveness, but in fact abysmally ignorant of the whole range of knowledge which adequate treatment of the sick requires, are a menace to humanity.

Little more can be said for the chiropractors and the naturopaths. First of all, they are advocates of low standards of preparatory education. Instead, I claim, unusually high standards should be the prerequisite. The art of healing is the only professional activity which is practiced by ostensible experts in the absence of other experts. Unlike the doctor, the teacher engages in public activity and may be under surveillance of a superior; the engineer has his work tested by inspectors; the lawyer practices in open court confronted by an opposing lawyer and a judge. The doctor, on the contrary, closes the door as he enters a home and thereafter what he does receives no higher criticism than that permitted by the judgment of a layman. The organized medical profes-

sion, realizing these facts, has done all that it could to make certain, when a novice begins the practice of medicine, that he shall know from laboratory study the practical aspects of anatomy and physiology, pathology, bacteriology and other medical sciences, that he shall be able because of numerous contacts with patients in dispensaries and hospitals to recognize all common varieties of disease or make the proper analyses for their determination, and then that he shall be ready in the treatment which the shared experience of trained physicians has proved to be most effective. To that end, as I have already noted, the prospective doctor spends about eight years in professional study and hospital experience. Such training is requisite before he is prepared to undertake the intimate, the delicate and often the onerous responsibilities of practice. It is the longest and most expensive of all professional preparations.

Compare this preparation with that required for chiropractors, naturopaths, sanipractors and their kind. Courses in the basal sciences are eliminated. A high-school preparation is sufficient in the best schools, and mature age, business experience or any convenient achievement is a satisfactory equivalent. The students are allowed to go forth from these "colleges" or "national universities" with a minimal attendance—the common requirement is eighteen months, but one so-called "university" is a correspondence school and grants a diploma for $127.50 after a course depending for its length on "individual ability." The schools are admittedly established on a business and not on a professional basis. The students are instructed not only in manipulative methods but in salesmanship. "We teach them the idea," the founder of chiropractic boasts, "and then we show them how to sell it!" Laboratory training in physiology, physiological chemistry, bacteriology, histology and pathology is, in practically all schools, wholly lacking. The subjects are either omitted or taught by didactic lectures or illustrated by quite inadequate apparatus. The teachers are in no sense competent; commonly they possess only the D.C. or Ph.C. (philosopher of chiropractic!) degree, and they are not paid salaries which permit them to satisfy scholarly interests, if they ever had any. They are not members of professional scientific societies. The clinics are not adequate for training in the diagnosis of even the most ordinary diseases. Indeed, as the catalogue of the leading chiropractic school once announced, "The chiropractor does not take the temperature, he never taps the chest or stethoscopically listens as in auscultation . . . he never looks at the tongue . . . in fact he makes no diagnosis or examination." All patients are considered from the sectarian point of view (according to chiropractic, diphtheria is due to subluxation of the sixth dorsal vertebra, scarlet fever the twelfth dorsal!) and the treatment is limited to the peculiar forms of manipulation. Naturally enough, representatives of these cults are frankly out of sympathy with the organized medical and public health interests established in the nation, the states and the large cities, and are openly antagonistic to many of the most universally recognized facts and procedures of civilized society—such as the bacterial cause of infections, the use of diphtheria antitoxin and antityphoid vaccination and the necessity of quarantine. No reliance is placed upon them by any agency responsible for the protection of the people against epidemic diseases, or against the dangers of food poisoning and bad sanitation. No signs of disinterested public service on their part are evident. No discoveries which have brought any benefit to humanity can be credited to them.

When we consider that the cults are

based on a theory of the nature of disease which is quite without any supporting evidence that has ever commended itself to critical judgment and which is wholly at variance with the well-proved facts of experimental and clinical observation; when we consider that the practitioners of these cults have no adequate scientific training, no trust in the methods which have freed mankind from vast and disastrous pestilences, no thorough discipline in the diagnosis of disease, and as a rule no versatility in their attack on disease but only the single method of projected thought or suggestion or vigorous handling of the body; when we know from court records that they have, for example, treated by such means diphtheria, peritonitis and bronchopneumonia; and when we realize that chances favor the practice of their methods on the most easily deceived and most credulous members of society, I believe that we are justified in regarding them as sources of danger, as actual enemies of society.

The question may properly be asked why these cults exist, why there are in our country nearly one fourth as many sectarian "healers" as there are practicing physicians. One reason, no doubt, is the present high standard of training for the practice of medicine. The cults afford a means of evading it. That standard was raised, however, because the organized medical profession, about thirty years ago, realized that there were many poor schools which were sending forth ill-prepared doctors and it set to work to close such schools and to put a premium on excellence. In consequence, the number of medical schools was reduced about half, and the remaining institutions were greatly improved in their methods of training physicians. Also the profession has supported the move to raise the state requirements for medical practice. We have still with us, however, the products of the earlier time, physicians whose training was fundamentally inadequate and whose services to the sick in any complex situation are likely to be unsatisfactory. But even if the trained doctor were a man of much less ability, insight and understanding than he is to-day, could that possibly justify admitting to medical practice less well-trained doctors? No! We need higher standards rather than lower.

Another reason for the existence of cults, that involves the well-trained physician, is that he frankly admits the need for studying a possibly obscure case before expressing an opinion about it. Many patients interpret such caution as ignorance and suppose that quick decision means knowledge. The "healer," with his prompt and positive assertions and his limitless self-assurance, is thus given credit which is withheld from the doctor—quite possibly to the disaster of the patient. Still another reason is found in the growth—may I suggest overgrowth—of specialism in medicine, with its attendant transfer of patients from office to office and the consequent high costs. Moreover, there are members of the medical profession who have been tardy in appreciating the psychic element in illness. Furthermore, the fact must be recognized that, with respect to disease especially, human beings often believe in the potency of magic. The "healer" is looked upon as a greater magician than the careful, scientifically disciplined doctor. Finally, individuals report that they have been *cured* by the procedures employed, a *post-hoc-ergo-propter-hoc* inference which wholly overlooks the self-corrective devices of the body and which has been used to justify every absurd therapeutic agency ever conceived, from the beating of a tom-tom outside a tepee to the prescription of western fresh-air pills. Not one of these reasons is cogent for the tolerance in

our civilization of groups of medical pretenders—ignorant, untrained, often unprincipled, and always dangerous both for what they do and what they do not do for those who resort to them. In the main the organized cults are found only in Canada and the United States; the rest of the civilized world manages well without them. An enlightened society would see to it that its innocent members who require skilled attention because they are ill receive intelligent professional service and are not exploited by charlatans.

Another group of enemies of society are the antivaccinationists. They object to conforming to the rules which have been learned about smallpox and thereby they not only expose themselves to the dangers of that disease but also they try to establish conditions which would expose to its attacks innocent children, not old enough to exercise independent judgment. Like the Black Death, smallpox has been at times one of the great plagues. Highly variable, it smoulders in mild attacks for a time, and then, if conditions in the population are favorable, it may suddenly break out in a violent epidemic. In 1802 Admiral Berkeley reported in the House of Commons, "In this United Kingdom alone 45,000 persons die annually of the smallpox; but throughout the world what is it? Not a second is struck by the hand of time but a victim is sacrificed upon the altar of that most horrible of all disorders, the smallpox." As the historian, Macaulay, has recorded, "Smallpox was always present, filling the churchyard with corpses, tormenting with constant fear all whom it had not stricken, leaving on those whose lives it spared the hideous traces of its powers, turning the babe into a changeling at which the mother shuddered." Frederick William III, of Prussia, in a dispatch dated October 31, 1803, stated that 40,000 people succumbed annually to smallpox in his kingdom. The French physician, De la Condamine, declared in 1754 that "one fourth of mankind was either killed by it or crippled or disfigured for life." So thoroughly infectious is the disease that it was reported by contemporaneous writers in the eighteenth century that as many as 80 to 90 per cent. of the population were marked as survivors of attacks of smallpox.

It is not generally known that in former times smallpox was essentially a disease of children, so much so that it was called "child pox." Then the adult population consisted largely of survivors of smallpox in childhood. In the small town of Kilmarnock, for example, there were nine epidemics of smallpox in the 31 years from 1728 to 1764. The total deaths from this disease were 622, and of these, 586 were deaths of children under six years of age; only 7 were more than ten years old.

It is not generally known that smallpox not only kills or disfigures and maims, but also destroys vision. The early records of the London Asylum for the Indigent Blind showed that two thirds of the inmates had lost their sight through smallpox. And according to Sir William Aitkin, 90 per cent. of the cases of blindness encountered in the bazaars of India are due to that disease.

Now what are the laws of that disease? Observation suggested that persons who had had an attack of cowpox did not contract smallpox. Jenner tested experimentally that idea and found evidence that it was correct. Then began vaccination with cowpox on a large scale. Human experience in all parts of the world has shown that a successful "take" protects against smallpox for a period varying on the average from 7 to 10 years, that when this immunity is exhausted a second "take" renews it, that persons twice successfully vaccinated are usually immune for

life, and that even when not fully immune, a vaccinated person who has an attack of smallpox suffers much less severely than a person who has not been vaccinated.

When the rules of this disease and protection against it are respected the results are striking. Careful statistics gathered in European countries clearly prove that those with most stringent vaccination laws suffer the least from smallpox, namely, Germany, Denmark, Sweden and Norway. In well-vaccinated Germany the mortality has been for years in the neighborhood of 1 person per 1,000,000 of the population. In England and Wales, where vaccination is generally but not universally practiced, the mortality has been about 20 persons per million per year. The experience of foreign countries has been duplicated in the United States. In Massachusetts, where there is a heterogeneous population of about 3,850,000, a fairly strict compulsory vaccination law prevails. In the ten years, 1919 to 1928, 408 cases of smallpox occurred. In the four states, Arizona, Utah, North Dakota and Minnesota, where compulsory vaccination is prohibited, the total population is almost the same as that of Massachusetts. During the same decade these states had 46,130 cases of smallpox, 113 times as many as Massachusetts! In Puerto Rico, where smallpox was an important disease before the American occupation, only 137 cases appeared in the eleven years, 1913 to 1923. In the unprotected state of Washington, with about the same population, there were, during the same period, 24,183 cases, 176 times as many as in Puerto Rico. If in the states decorated by the antivaccinationists with gold stars, fear does not drive many of the citizens to the protection afforded by vaccination, a serious outbreak of smallpox may be reasonably anticipated such as occurred in Montreal in 1885–86, when the pestilence in its violent form swept through an unwary people and killed 3,164, of whom nearly 87 per cent. were children not yet ten years old.

If men and women were isolated individuals, not living together in communities, they might properly exercise their individualism and refuse to be shielded by vaccination, even though its value as a protective measure has been repeatedly proved. But when they live in communities, such of them as are not vaccinated, and are therefore susceptible to smallpox, afford means for the spread of the disease. As it spreads among adults it has opportunities of attacking unprotected children in whom the mortality is highest during the first years of life. Those who advocate abolishing the vaccination laws are demonstrably threatening the lives of helpless infants and are properly branded as enemies of society.

The last of the enemies of society whom I shall consider are those who oppose the use of lower animals for the purpose of experimental inquiry into the nature of disease and into the best modes of treatment. The "antivivisectionists," so-called, are potentially the greatest menace of all, for if their ideas should prevail, the means of continuing the progress which has thus far been made in freeing mankind from debility and premature death would be sharply stopped. That statement can be made with complete assurance of its being correct, because in every aspect of the conquest of disease, the understanding of infection, the progress of surgery and the establishment of measures for public health, mentioned earlier, the experimental methods required the use of lower animals.

In tracing the history of the antivivisection movement it is interesting to compare the testimony before the English Royal Commissions of 1876 and of 1906–10. In the earlier hearings, held only a few decades after the experi-

mental method began to be used effectively for physiological discovery—before the sciences of bacteriology, immunology, biochemistry, experimental pathology and pharmacology had begun to emerge as special disciplines—the emphasis of the antivivisectionists was on the futility of animal experimentation. The defenders of scientific methods in biology had a difficult task to make clear the importance of keeping open for the uses of medical investigators the well-tried ways of experimental discovery, as proved by the advances in physics and chemistry. How different were the hearings thirty years later! At that time by means of animal experimentation the causes of tuberculosis, bubonic plague, diphtheria, surgical sepsis, child-bed fever and other diseases had been discovered; by use of animals the method of detecting socially dangerous diseases such as typhoid fever and cholera had been learned; and by similar experimental procedures effective natural methods of preventing diseases or curing them (as with diphtheria antitoxin, for example) had been devised. The claim of futility had to be modified. Still more must it be modified to-day, because we can now add to the earlier achievements the control of syphilis, the relief of general paralysis, the swift betterment of scarlet fever patients, the check on diabetes and the rescue of victims of pernicious anemia—we can add these victories over disease and death that have recently been won by medical discoveries made directly or indirectly by use of lower animals.

One might suppose that all this evidence would force the antivivisectionists to admit the utility of animal experimentation. To do so, however, would mean a great weakening of their position, for their main argument from the start has been that the process is futile and cruel, and that such futile cruelty should be stopped. The evidence, however, has caused them to change their emphasis. They now say that, even if animal experimentation has values, the values are purchased at too great a price. The animals used in experimental laboratories, they declare, are subjected to fiendishly cruel tortures, tortures too awful to be permitted to continue, no matter what benefit may come therefrom to mankind. In their present view, the question is ethical. The animals have rights which we must respect. Not to do so, in so far as laboratory use is concerned, is an affront to the finest feelings in the heart of man and is the cause of callousness and brutality in the experimenter which lead him gradually into worse and more extreme and more degrading acts of violence. Therefore, away with the whole hideous process. Abolish it. Shut up the medical laboratories. Stop studying disease experimentally, stop trying to find remedies by animal tests. That way is closed.

Who are these antivivisectionists, may I ask, that any one should respect their opinion as to what shall and what shall not be done to save human life? Judged from the appearance at legislative hearings and the quoted opinions in their literature, they comprise many women, a few clergymen, some lawyers, writers, actors and business men, who, however sincere and well-intentioned, are grossly misinformed. They cite for support of their attitude the opinions of so-called "doctors," who on investigation are found to have died so long ago that they had no knowledge of the beneficent effects of modern experimentation, or who are devotees of fantastic medical cults, or who made their reputations in literature, art or theology and not in the service of healing. As the second English Royal Commission reported, their "harrowing descriptions and illustrations of operations inflicted on animals, which

are freely circulated by post, advertisement or otherwise, are in many cases calculated to mislead the public." Neither the quick nor the dead among the antivivisectionists testify on the basis of actual experience. They have not entered the laboratories in which they declare that animals are wantonly tortured, they have not seen the operations they criticize, they have not had the background of experience which would allow them to judge properly the reactions of anesthetized animals, they have not had the training which would permit them to interpret intelligently the technical articles which they read, and in place of personal acquaintance with the facts they have let their sentiments and their imaginations have full sway.

For more than forty years in this country members of the medical profession have been fighting to maintain freedom of research. From the first they have claimed that nothing has been adduced to warrant the passage of special, class legislation directed particularly against medical investigators, but that the ordinary anticruelty laws are as applicable in the laboratory as in any other place. All that need be done, if cruelty is suspected, is to make a charge and demand an inspection. Never, to my knowledge, in all these forty years has any antivivisectionist made use of the existing law in this manner.

About twenty-five years ago the American Medical Association established a Committee for the Protection of Medical Research. Immediately it began an inquiry into the conditions under which animal experimentation was being conducted. It found that for years in the older laboratories rules had been formulated and prominently posted, declaring the precautions and expressing the humane spirit which should govern the experimental procedures. These rules the committee summarized and revised in such ways as to render them generally applicable. By the end of the year 1910 these revised rules had been adopted in practically all laboratories of medical schools in the United States. They have since been adopted in institutes for medical research and in many laboratories of state and city boards of health. Thus, by self-imposed regulations, investigators have publicly defined the safeguards which had been taken and which would continue to be taken to avoid the infliction of pain and thus they have made clear to all who enter the laboratories that work done there shall exhibit that intelligent compassion characteristic of medical service. I would emphasize the point that this mode of self-government of investigators who use lower animals for biological research and for solving problems of disease has been enforced in some of our most prominent medical schools during the past half century.

So certain was the committee that the conduct of animal experimentation in the United States is in the highest sense humane that in 1921 it secured the adoption of the "open door policy." In accord with that policy laboratory officials throughout the United States declared their willingness to admit at all times representatives of humane societies who might wish to know the conditions under which animals are used for research. The only condition laid down was that such visitors must previously have seen an operation on a human being in order to be able to appreciate the humaneness of the laboratory methods. This policy was given a large publicity. In 1922 the Blue Cross Society, an organization for the humane care of animals, widely circulated excerpts from the letters of deans and directors of departments, testifying to the enforcement of the rules for the regulation of animal experimentation and to the maintenance of the open door policy.

Such are the conditions under which animal experimentation is now carried on in the United States. The medical investigators testify that they know nothing of the tortures, the horrible cruelties, the secret atrocities which, in the imagination of antivivisectionists, are inflicted on helpless animals in laboratories. The investigators declare, in fact, that the vast majority of operations on animals are practically painless. And in spite of being branded as "fiends," "demons," "human monsters," the investigators are, I believe, persons whose word can be trusted. They are trained scholars; as men of science their service to their fellow men consists in the search for and the establishment of new facts; their eyes and ears are exercised in exact observation; and they are constantly disciplined to draw only justifiable inferences from what they observe. It would seem, therefore, that they are fairly well qualified to report the events going on about them. When they report, they do so fully and precisely, in order that others, who may wish to follow their course and push further into the unknown, shall not be led astray. Desire to find something new and important and verifiable and the wish to report exactly what is found are the ideals which govern the activities of scientific investigators. The pursuit of these ideals is excellent training in telling the truth.

We should recognize that these investigators are the direct successors of the pioneers who, according to Osler, by the experimental study of physiology and pathology "did more in the half-century between 1850 and 1900, to emancipate medicine from the routine and thraldom of authority than all the work of all the physicians from the days of Hippocrates to Jenner" (about 2,200 years!), and he added, "we are yet but on the threshold."

That in brief is the gist of the situation. In a few decades the application of the experimental method in medical research has wrought marvelous advances in our ability to conserve human life. I need not list again the diseases brought under control or abolished, the release from appalling dread, the opening of the door of hope, that have resulted. But there is much more to be done. We have not yet mastered measles, nor fathomed the mystery of infantile paralysis, nor have we learned the secret of the world-wide plague-like visitations of influenza, we know little of the cause of fatal maladies of the kidneys and the liver, we stand almost helpless before mental diseases, victims of which fill more than half of our hospital beds; and without surgery we are unable to deal with the awful scourge of cancer which kills about 1 man in 7 and 1 woman in 5 if they have passed their fortieth year.

Knowing, as we do, that the method of animal experimentation alone has largely delivered us from the bondage of disease, and certain, as we are, that that method gives us the fairest promise of further deliverance, what shall we do? Shall we cease our efforts, as the antivivisectionists demand? Shall we let men, women and children, whose suffering extends to every one bound to them by love and sympathy, continue their suffering because its cause is a mystery, which we must not solve? In the presence of human woe is it immoral to use lower animals to mitigate that woe? We do not hesitate to interfere with the liberties and life of animals for other human benefits.

We force the harnessed horse to work, and in time of crisis, we drive him with lash and spur. We rob the mother cow of her calf, and then appropriate her milk. We permit the dehorning of cattle and their branding with hot irons. We do not object to the most shocking barn-yard operations, performed (without the sniff of an anesthetic) merely to make more

palatable the flesh we eat. We slaughter ruthlessly, for sport, myriads of birds and beasts. Myriads more we slaughter for their furs and feathers. We kill for food every year in this country more than 50,000,000 beeves, sheep and hogs, and also 250,000,000 chickens, turkeys, ducks and geese. In nineteen of the largest cities in the United States more than 350,000 dogs and cats are destroyed annually, merely to clear the streets. Vermin and wild animals we subject to death in uncertain traps or end their existence with distressing poisons. If all injury and destruction of animal life is immoral, why do the antivivisectionists select as an object for attack the treatment of the relatively few animals employed in the laboratories with the object of reducing pain and suffering in the world?

But as Professor John Dewey has clearly seen, the question at issue is not merely a balancing of physical pain of human beings and of animals against each other. Instead, "it is the question of a certain amount of physical suffering to animals—reduced in extent to a minimum by the precautions of anesthesia, asepsis, and skill—against the bonds and relations which hold people together in society, against the conditions of social vigor and vitality, against the deepest of shocks and interferences to human love and service."

"No one who has faced this issue," Dr. Dewey continues, "can be in doubt as to where the moral right and wrong lie. To prefer the claims of the physical sensations of animals to the prevention of death and the cure of disease—probably the greatest sources of poverty, distress and inefficiency, and certainly the greatest sources of moral suffering—does not rise even to the level of sentimentalism."

"It is accordingly the duty of scientific men," he declares, "to use animal experimentation as an instrument in the promotion of social well-being; and it is the duty of the general public to protect these men from attacks that hamper their work. It is the duty of the general public to sustain them in their endeavors. For physicians and scientific men, though having their individual failings and fallibilities like the rest of us, are in this matter acting as ministers and ambassadors of the public good."

There is a statement in the last paragraph, which I have just quoted, that I wish to emphasize — it is the duty of the general public to protect medical investigators from attacks that hamper their work, and to sustain them in their endeavors. That is a welcome note. For decades these investigators, unlike their fellows in physics and chemistry, have had to appear almost annually before legislative committees to argue for the privilege of continuing unhampered their services to human welfare. Although many scientific societies have passed strongly favorable resolutions, only the organized medical profession in the state and the nation has given active support. It is high time for society as a whole to recognize that it has in the antivivisectionists dangerous and resolute enemies and to take steps to thwart their efforts.

In conclusion, may I point out that the medical profession has not only helped to protect society from being endangered by the pernicious activities of the antivivisectionists, but also from being misled and deceived by ignorant "healers." In the main the profession has urged that all who wish to practice the art of healing should submit to the single standard of passing an examination on the structure and functions and the possible disorders of the human body, before being allowed to practice. Because it has supported that fair and uniform requirement, which would prevent quacks and charlatans from exploiting the uninformed and incautious sick, the medical profession has been charged with being a ruthless "trust," seeking solely its own advantage, and eager to exclude all competitors. That charge of corporate selfishness might be

entertained if there were any evidence to sustain it. The historical record, however, is against it. The medical profession has from the beginning supported measures for public health; it has supplied the health officers who protect our cities and coasts; it has agitated for clean water which has abolished the devastating water-borne typhoid epidemics; it has worked for conditions which have greatly lessened the incidence of tuberculosis, yellow fever, malaria and hookworm disease; in its own group it has insisted on high standards of education and professional service—in short, as these illustrations demonstrate, the profession has sought to abolish, not to increase, disease; it has striven earnestly, not for its own advantage in the mean sense of the word, but for the advantage of the social organism of which it is a part. Whenever any other professional groups—lawyers or engineers, for example—can show a record that even remotely approaches that of our own for disinterested public service, we may begin to think that we have not kept up our traditional reputation. For the present we lead. But we usually lead as an isolated and distinct group in the community—as a medical "bloc." Since our purposes and those of society are really one, we should cooperate to a greater degree with intelligent and social-minded members of lay organizations. Thus the medical profession would serve, not as a separate organ of the body politic but as one of the cooperating parts, helping, and not carrying the whole responsibility, in the defence against social enemies. By such an alliance the threatened intrusive perils from organized minorities can be effectively met. Concerted action of public-spirited physicians with well-informed members of the community—members of women's clubs, chambers of commerce, parent-teachers' associations—could change the defense to aggressive attack. And by aggressive attack we may hope for still further freedom—freedom from the dangers to the common weal from spurious "doctors," from persons who refuse to accept measures to protect the public health and from fanatical agitators who strive to check the beneficient advancement of medical knowledge.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

WAYS OF THE BEAVER PEOPLE

By VERNON BAILEY

U. S. BIOLOGICAL SURVEY

THE old Indian idea of considering many animals as just other kinds of people, different from our kind but not so very different, is evidently based on close association and real understanding of animal habits and natures. Their Coyote Man, the Bear People and the Beaver People are significant terms. They often name their sons for some animals of special bravery, prowess or intelligence, as no doubt our ancestors did before the psychologists tried to prove a wide and impassable gap between man and other animals that we class as lower down in the scale of life. There are great differences, but mainly mere differences of degree.

There has been much romance written about the beaver, but nothing more interesting than the actual facts. They are not human nor superhuman, as some would have us believe, but they are very intelligent animals in their own way, and from youth to old age they lead interesting and useful lifes, if given half a chance.

The baby beavers, Paddy and Johnny, that Mrs. Bailey and I raised from a few days old in early June to big husky young beavers in the fall, were very like children in the family. They had many of the ills and accidents of children, cried exactly like babies when hungry, loved to be rocked to sleep after meals and to be wrapped in their woolen blanket and taken into a warm bed when they were cold. In return they gave us the most friendly confidence and a slight degree of obedience.

Another pair of young that, before I knew them, were kept all summer for exhibition to the public at county fairs took a strong dislike to the human species and never became friendly. When given a comfortable and convenient house in the park, with a warm nest box and a water hole into the pond, they were happy until I came in through the back door. Then they slapped their tails on the wet floor and refused to be comforted until I went away. That night they piled all their sticks against the door to keep me out. When this was not successful, they went around behind the house and piled sticks and mud against the outside of the door almost to the top and plastered up the cracks with mud as high as their skilful hands could reach, with the evident intention of barring me from their home. Later, when I had to catch them and saw off their upper incisors, which had grown too long from lack of wood to cut, they were very angry and tried both to escape and to bite me, although they were not being hurt in the least by the necessary dentistry. Another beaver in the house with them, caught in the wild when full grown, was comparatively gentle and friendly.

The only other beaver I ever handled that was cross with me was an old female that had previously been caught in a steel trap and lost one foot and naturally had gained a very poor opinion of human people. She would actually chase me until I was glad to put her back in the lake where she came from.

To test the intelligence and skill of an Adirondack beaver, I once cut a notch in the top of a well-kept beaver dam that held the water in a clear deep pond surrounding a large beaver house. This was before sundown in the afternoon of a bright autumn day. The beavers had been cutting and storing wood for their winter's supply of food to be eaten under the ice, and they knew as well as I the importance of keeping the pond full of water.

After seating myself comfortably on a high bank above the dam I waited while the water roared out through the break with a sound that easily carried through the still water to the beaver hole in the bottom of the house where the family lived. In about ten minutes a ripple appeared near the house, and then a V-shaped wake came directly toward the broken dam, its apex marked by a blunt nose, two bright eyes and a pair of low round ears. As the wake stopped close to the break the broad back, flat tail and webbed hind feet of a large old beaver floated at the surface for a full minute, while with keen senses alert it studied the surroundings for a possible enemy. It may have been Mrs. or Mr. Beaver. No one could ever tell in the water and few can tell on land, but we will call him "Mister." The coast seemed clear, for I was above and down the wind and knew how to keep still.

Soon the old beaver came up into the break, sat in the rushing water, and eyed the broken banks on both sides. He was evidently puzzled for any logical cause of the trouble, but his thoughts were of a practical nature. Returning to the pond he disappeared just above the dam and soon came up with both arms full of mud and trash from the bottom, pushed it up on the dam and into the broken notch, sat for a minute and watched while the rushing water carried it all away, then started up the pond to a steep bank and cut off a stout bush. This he brought to the dam and with both hands and his teeth pushed the butt end into the mud at one side of the break. Then he swam out in the pond, dived to the bottom, brought up a stick about two feet long, swam with it in his big teeth back to the dam, and pushed one end down into the other side of the break. Then, without stopping longer than to see that it held firmly, he swam to another spot in the pond and brought up a long limby stick and laid it crossways against the two sticks, clear across the rushing stream. It stayed where placed, but only made the angry waters roar the louder. The beaver then brought up another big armful of trash from the bottom and pushed up against this cross stick and as rapidly as possible brought load after load of mud and trash until the water stopped roaring, then stopped running over the dam, and the job was done.

I forgot to look at my watch, but should guess at the time as twenty minutes for the whole repair job. It was thorough, final and satisfactory, and after carefully inspecting it the beaver went back to the house and disappeared underneath by way of the water door into his comfortable nest room inside. This was just an incident in his day's work, but it showed thought, planning, skill and understanding. All it lacked of human intelligence was the bill for five dollars for plumbing repairs that he should have sent to me.

A well-made beaver house beats any barbed-wire entanglement for strength and impenetrability of structure, besides being cold-proof in winter and heat-proof in summer. It may have an unkempt appearance externally, but inside it is a model of comfort and convenience. With a clean bed only a little above the water door in the bottom and a little extra room for sticks that are brought in for food, housekeeping is simplified to its lowest terms. The bathroom is out-

side and there is plenty of room in the lake or pond for social affairs.

There are also bank burrows, which often are safer than houses, because they are entered below the water level, in high lake or stream banks where well hidden from all enemies. The nest chambers are as safe and clean and comfortable as could be desired, and the entrances are deep under water.

Beavers are hearty eaters, and the problem of an ample winter food supply is of vital importance. Enough good green wood must be cut and stored in deep water to last the beaver family or colony through the winter, or from the time the ice seals the ponds late in fall to the time when it breaks up in spring. Only the fresh green bark, twigs and buds are eaten, so it takes a lot of wood, and many trees must be cut down, cut into sections that can be dragged to the water and floated to the storage place. Often long canals must be dug through the low ground so heavy sticks and small logs can be floated most of the way from the woods.

This keeps the whole family working like beavers all through the fall storage time right up to cold weather when the ice comes to stay. Everybody works. The big old male may lead the way, but he is eagerly followed by the mother beaver, who may be just as big, strong and wise, by several husky yearlings, and last of all by four or five young of the year, eager to help. While at first mainly in the way, the young soon prove very useful in carrying branches and small sticks to the food store. There seems to be no supervision, no subdivision of labor, no idle boss, but everybody knows what to do and how to do it and enjoys hard work and long hours.

At my camp on the edge of a beautiful lake in northern Michigan the whole gang would swim by to their cutting ground before dark and come straggling back to their house just before sunrise in the morning. The big old patriarch would be the first to start and often the last to return. Every morning showed more clean-cut stumps and less aspen trees standing in the sidehill grove where the beavers were cutting their timber, and because the trees were small and some of the beavers large, not a tree was left on the ground or lodged in the branches of other trees, as often happens. They were building a new house and making their stores near it, but still sleeping daytimes in a big old house just beyond my camp, so I had a good chance to watch them as the work progressed.

Before the lake froze over they had a regular haystack of logs and sticks and branches of aspen, birch and alder resting on the bottom of the lake in ten feet of water, with brushy tops sticking out above the surface. There were tons of it, all to be peeled and the bark and twigs eaten before spring. Most of it would be cut in short lengths and carried into the house and eaten at leisure, but the larger pieces would have the bark peeled off and eaten where they were, for beavers' mouths are arranged so they can chew and eat under water as well as out.

I wasn't there the following spring, but last spring's remains of peeled sticks over the bottoms of the lakes and ponds near beaver houses were ample evidence of the winter activities. A few sticks are generally found in a beaver house, but when the bark is eaten they are soon carried out. Even the bare peeled sticks are not wasted, for they are just right for building up the house walls and beaver dams when needed. In summer there is abundance of good beaver food everywhere, in the water and out, all sorts of good green leaves, tender growing stems, nice starchy roots and bark when they want it. Winter has been a restful playtime, spring is full of leisure and tempting odors and wanderlust.

Mrs. Beaver must stay at home, for

she will soon have a new family of four or five or six dear furry little paddle-tailed babies to care for, and the old house must be fixed up safe and warm for them or else a clean fresh burrow and nest room made in a high bank where nobody can ever find them. She will be busy and couldn't think of leaving home, but Mr. Beaver and all the last year's children can go where they please and see as much of the under-water world as they like. They will not be needed until next fall when the food harvest begins again.

If it wasn't for their beautiful fur coats and the heartless fur trappers, they would live happy and contented lives and have less to worry about than some of our people have. If the trappers would display more intelligence and use only live traps that would catch the beavers without any injury or discomfort and then release all but the older animals that had outlived their usefulness and had prime pelts, there could be plenty of beavers anywhere in suitable places. They would then be a valuable asset to the country and one of the most interesting forms of wild life for our study and for the enjoyment of all who are interested in a better knowledge of our animal friends.

The beavers' good-by is a slap on the water with his tail, so — — —

FIGHTING INSECTS WITH POWDER AND LEAD

By Dr. A. L. MELANDER

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FIRST of all, this title suggests the old story of the woman asking the drug clerk for a package of powder. "What kind of powder to you wish—gun, face or insect?" When man wages war on man powder and lead are used, and in the warfare against insects insecticidal powder and lead as poison and lethal gas are employed. The powder is a poisonous dust, the lead is combined with arsenic as arsenate of lead, and the gas may consist of nicotine fumes or deadly cyanogen. Chemical warfare on insects has become an accepted part of our yearly life. It will never be outlawed because of humane feelings for our enemies, and in time to come will decide whether man or insects will dominate this world.

From earliest times insects have afflicted man, destroyed his crops, spread disease and attacked his domesticated animals. As more and more land is farmed, insect pests have increased in numbers and in their depredations, until now in the United States alone insects destroy each year the products of the labor of a million men, a money loss of at least one and one half billion dollars.

There are many million-dollar insects, several species costing us even a hundred million dollars annually by their destruction of our food and by the expense of our attempts to check their depredations. Chinch bugs swarm in the fields of corn and wheat of the Middle States; the wheat aphis and the Hessian fly of the Mississippi Valley ravage the wheat crop; potato beetles have invaded practically every potato field throughout the continent; the San José scale has spread so rapidly through orchards from coast to coast as to make necessary state laws for the compulsory spraying of fruit trees, the sorting and grading of picked fruit and the condemnation of all fruit found infested; the codling-moth makes

apples wormy, for the control of which an army of men must spray trainloads of poison over millions of apple treees.

The combined destructiveness of the insects just mentioned amounts to hundreds of millions of dollars each year. These insects are racketeers, who exort this toll from the producing farmers, and then the farmers, of course, must pass the cost on to the consuming public. We may think that five cents is cheap for a loaf of bread, but if there were no insect pests of wheat the cost could be four cents. When we pay five cents for an apple we should remember that one cent of this goes for the spraying which alone made it possible for that apple to appear on the market. If the spraying had not been done, that apple would have been wormy or scaly or scabby or deformed by aphis, and unsalable.

People who live in cities have little idea of the actuality and the extent of the warfare waged upon insects. The household atomizer is replaced by motor-driven and operated spraying machines. Trainloads of spray-poisons are used. Whole communities of men participate in the battle. Of the twenty-seven million people who live on farms in the United States, nearly all at some time or other must aid in fighting insect pests.

In the Middle West, county campaigns are organized to distribute poisoned bran for grasshoppers. In California, orange groves are subjected to poison gas, the trees being covered with canvas tents and deadly cyanogen gas administered within. In the South, airplanes shower poison dust over cotton fields to destroy the boll weevil and the boll worms. In every commercial orchard from Washington State to New York State, the chugging of engine-driven spraying machinery can be heard.

While the number of insect enemies may appear large on account of the aggregate of their depredations, the actual number of insects pests is fortunately small. Of the insects found in any locality, the vast majority are of little consequence to man, neutral to our economy, feeding on wild plants or upon each other. Only relatively few species are pests in that they eat the plants we grow for our own food, or harm our animals, or even directly attack ourselves. However, since insects far outnumber all other animal species taken together, there is scarcely any limitation in possibilities that insects may become pests when transported to new localities. We do not know what is in store for us, as the future will introduce new insects to this country from foreign shores.

Far-reaching consequences often originate in trivial happenings. When in 1866 an amateur entomologist in Boston imported some specimens of the gipsy-moth from England in an effort, so the story goes, to cross this insect with American moths, hoping thus to develop a silk-producing strain, his experiments might be regarded as praiseworthy, or at least of nobody's concern. Certainly no one at that time could foresee the portentous consequences when a specimen escaped from the cage into the woods near by.

The progeny of that alien moth have caused millions upon millions of dollars to be expended in New England alone, in the unsuccessful attempt to exterminate their race. Huge federal and state appropriations have repeatedly become necessary to subjugate this pest. The Gipsy-Moth Commission was created to investigate ways and means to keep the moth from spreading. Forces of inspectors have had to be maintained. Expert entomologists have scoured Europe and Asia in order to discover the natural parasitic and predatory insect enemies of the moth and to liberate them in the stricken regions here. The extensive warfare upon this invader has exterminated many innocent native insects, whose right to a place in this world

would not have been questioned. Quarantine laws have worked economic hardship on the sellers of produce from the infested localities, Christmas trees, lumber and even quarried granite having been banned as possible carriers of the eggs of this moth. In order to guard against the introduction of other insect pests, federal quarantine laws have been enacted, which at times have threatened diplomatic relations with countries whose produce has been refused admission to the United States.

The gipsy-moth in its caterpillar stage is practically omnivorous. It feeds on the plants of the farm, in woodlands and forests and on ornamentals. It is prolific and exceptionally hardy. Its eggs are often concealed. Many of its caterpillars feed in the tops of trees out of reach. With no knowledge of practical insect control available fifty years ago, no wonder that the destructive spread of this insect through New England was regarded with alarm, lest it sweep across the entire country and its billion dollar toll be multiplied manyfold.

The gipsy-moth is widely distributed through Europe and Asia, but it is not particularly destructive there. In the long ages it has reached a state of equilibrium, held in check by its native enemies. Certainly no country in Europe or Asia would appropriate millions of dollars for its study and suppression. But coming to America, unhampered by its parasites and predators, it was free to propagate and it spread with startling rapidity.

Similar unrestrained multiplication has commonly followed the introduction of other pests to this country. Most of our serious destructive insects are not native, but have come to the United States from near or from far. The San José scale was accidentally brought from China, the bean beetle and the boll weevil from Mexico, the fluted scale from Australia, the codling moth, oystershell barklouse, red spider, earwig and many kinds of aphids from Europe. Such names as Japanese beetle, European corn-borer, gipsy-moth, Mediterranean fruit-fly and Asiatic beetle impute that these insects are not native Americans.

The United States has been the land of the free to many foreign insects, but now such anti-social immigrants have greater difficulty of introduction because of the inspection maintained by various border-line states and by the Federal Plant Quarantine and Control Administration, through whose vigilance it is hoped that the costly mistakes of the past will not be repeated. It is impossible to tell beforehand whether an insect species of little consequence in another country when brought to America may multiply prolifically and do immeasurable harm.

Before the gipsy-moth invaded Massachusetts, insect poisons and spraying methods were almost unknown. The Gipsy-Moth Commission established by Congress entered a pioneer field. Its investigators had to invent and develop pumps and nozzles for spraying and experiment with possible poisons. Their problem was to find a substance poisonous to the insect, yet harmless to the foliage on which it was applied, something economical, durable, easily mixed and applied, compatible with other materials, adhesive, not distasteful to the insect, and quick acting. It was probable that no such substance existed. Many known poisons when tried proved to be injurious to the plants when fatal to the caterpillars. Many washed away during rains. Some were repellent in taste. Others were too expensive for general use. Arsenate of lead alone possessed the attributes of an ideal insecticide, but hitherto it had found no use and was merely a chemical curiosity, only a few ounces of it being in existence in chemical museums. Now it is a staple com-

modity made by thousands of tons at a cost of but few cents per pound, and is used not only on the gipsy-moth but as the main protection against all fruit- and leaf-eating insects of orchards, garden, field and forest the world over. The act of Congress in establishing the Gipsy-Moth Commission laid a foundation for a new science of applied entomology.

If the gipsy-moth had not been a spectacular insect, and if it had not first invaded the property of influential Bostonians, and if Congress then as now had been motivated by nearsighted policies for economy, perhaps this scientific commission to discover means of repression of this local immigrant might have been regarded as an unwarranted extravagance. Time has shown that the far-reaching benefits from this study, however, have repaid the costs a thousandfold, and this should be remembered when retrenchment arguments are made against preparedness for the next insect war.

Some people excuse war because it brings out inventions and teaches efficiency, that while war brings immediate hardships its far-reaching results are beneficial. Such people find in the war-cloud against insects a silver lining in the discovery of improved methods of pest control, better farming practise, an improvement in the quality of fruits and crops and better prices to the producer. It is true that the scientific investigations necessitated by the gipsy-moth, the cotton boll weevil, the San José scale, the codling moth and other major insect pests have enabled farmers to produce crops despite their enemies.

If we knew no more about insect control than our grandfathers did, the greatly increased number of insects now occurring in the United States would bankrupt us as a farming nation. In a sense scientific methods have led to an overproduction of some products just now. Last year produced more cotton, corn, wheat, oranges and apples than found a profitable price on the market, but this condition was due to marketing inefficiency and the economic depression rather than to the growing of too much produce.

The world is still increasing in population. Statisticians assure us that at the present rate of increase of births over deaths forty million more acres of land must each year be brought into cultivation than the year before to keep us in food, that each year the world must produce twenty-three trillion pounds of food more than the year before. Since the amount of unoccupied land suitable for farming is decidedly limited, the time is not far distant when an outbreak of some insect pest will bring wholesale starvation. Perhaps our grandchildren, certainly our great-grandchildren, will know what it means to go hungry because the grasshoppers have eaten the wheat and corn.

People in China and India already perish by the million because of insect-spread diseases and because of crop failure. Horses and cattle on the Western range drop of starvation, due to drought and locust attack. Before them herds of bison were exterminated when hordes of insects wiped out their feeding grounds. It is a truism that the most deadly enemies are the small ones. Cutworms and grasshoppers are destined to be more terrible destroyers of mankind than wolves and lions.

Applied entomology is a youthful science, and with the boast of youth it realizes its achievements and importance. But it also knows that pest control requires continued investigation. Powder and lead have made possible the growing of some crops, but it would be folly to limit our dependence to their aid. The strength of the spray, the proper formula, the use of spreaders, adhesives, lures, baits or repellents, the possibility or impossibility of combining various

treatments and the time of application can not be predetermined, but require detailed experimentation. Some insects can not be reached by spraying; sometimes it is impractical to spray. Fruit-growers dread the accumulation of arsenicals dripping into the soil. Boards of health condemn oversprayed fruit. Some insects seem to be developing a resistance to standard treatments. Should pests in general become immune to treatment, the import is most ominous.

As a matter of present economic relief to the farmer and to the ultimate consumer, as well as preparedness against inevitable future invasions of insects, it behooves us as a nation to find means to stop the billion dollar waste caused by these Lilliputian enemies. Curtailment of appropriations for scientific investigations is certain to prolong a period of depression and not to terminate it. In biblical times, when the locusts swarmed over Egypt, the afflicted peoples turned to Moses for relief, and he said "Let us pray." Nowadays the materialistic farmer appeals to the entomologist, and he says "Let us spray."

PLANT SOCIOLOGY

By Dr. HENRY S. CONARD
PROFESSOR OF BOTANY, GRINNELL COLLEGE

THE youngest and newest of the great family of plant sciences is plant sociology. It has a definite history of about fifteen years. But in truth it is a development of good old common sense about plants as they actually grow in nature. It attempts to put in order what all field botanists, farmers, foresters and flower lovers know, and to enrich and deepen and organize this knowledge.

The word sociology can be applied to plant life only in a somewhat figurative way. In human society we have the conscious cooperation of individuals or the conscious lack of cooperation, directed to the accomplishment of some aim or plan for future achievement. Obviously this does not occur in plant societies. Trees may get their heads together, but they do not lay plans.

But there are also many social relations in human and animal societies which come about without any planning. The mere existence of two persons within the ken of one another brings about a social relation. It is in this latter way that plant sociology resembles the sociology of August Comte. Plants do live together in social units, each plant having an influence upon all the plants in its vicinity. This sociology, both of humans and of plants, has to do with the life of organisms in social units, as distinguished from the life of the individual by and for itself.

The mutual relations of plants may be classed as either dependent or commensal. The parasitic plants which cause disease upon other plants, and even that popular parasite, the mistletoe, are obviously dependent upon the host plant for food and shelter. But our most beloved spring flowers which grow in the rich leaf mold of our forests are just as truly dependent plants. For we all know how quickly the wildwood flowers die out when the forest is cut away. And many of us know that if we would have wild flowers in our gardens, we must provide them with shade and leaf mold.

Nor is leaf mold all one thing. The decay of pine needles produces a strongly acid mold. Oak leaves give a mildly acid humus. But the leaves of

willow, cottonwood and elm produce a neutral, or may even permit a feebly alkaline mold. And so the small plants of the coniferous forest are different from those of the oak woods, and these again differ from those of the river bottom woods of elm, willow and cottonwood.

In another aspect, the trees and flowers are commensals. They feed from the same table, without interfering with one another. The trees need lots of sunshine and they get it. They need constant supplies of water, and their roots go deep to get it. The shade plants want the subdued light which the trees afford; and they are content to draw their food and water from the surface soil which is useless to the trees. Here, then, is a friendly mutualism—a society without competition, but very distinctly a social union.

The minute sociological study of plant societies has yielded highly important results in the hands of European botanists. It is as yet undeveloped in America. Dr. York, when forester for New York State, remarked that when he took European foresters out to see our woods, they scarcely looked at the trees but examined critically the flowers and shrubs and mosses that grew under them. One can read volumes of reports about the trees. But the other members of the society have not been described. And it is exactly these other members, which elucidate the inner nature and the essential details of the social union, the forest. Some of us go abroad, put up at a dozen or two of the best hotels of Europe, and come home full of ideas about social conditions there. We are like foresters who look only at the trees. A sociologist knows that a hotel lobby—especially that of a hotel for tourists—is the last place in which to learn anything of value about a strange country. To learn of social conditions is a long, arduous and technical procedure.

So in plant sociology, an adequate knowledge of plant societies is the product of years of minute and painstaking research. Much can be learned from Rübel's delightful book on "Geobotanical Research" and his more recent one on "Plant Associations," and from the recently translated work of Lundegardh, and from the just announced translation of Braun-Blanquet. In these books many familiar facts find precise expression and a place in the cycle of science.

The old herb gatherer, now nearly extinguished by his own improvident methods, and by the synthetic chemist, was a practical plant sociologist. He knew where to look for gold thread or ginseng. But he didn't know why. Consequently, when natural ginseng became scarce, and it was necessary to cultivate it in order to supply the demand, it was a matter of long experimentation to find out how to meet its exacting requirements. The woodsman knows where to look for valuable maple or hickory or fir. But when it comes to reforestation, the attempts of the woodsman, and even of the forester, often fail. The social relation has not been taken into account. We are still going at it rather blindly, owing to the inadequacy of our knowledge of the social relations of plants.

The farmer can tell a good deal about his soil and its needs by the behavior of crops and weeds in each field. And a good deal has been done in our western plains by Clements and Weaver and their school on the so-called "indicator" value of certain plants or groups of plants. Sage brush will indicate the possibilities of the soil and climate over large areas of our semiarid west. Sage brush land will produce crops if water can be given in sufficient quantity. Greasewood land is alkaline and is either hopeless or will yield crops only after prolonged washing. The purslane weed survives only in cultivated or very re-

cently cultivated land. Jimson weed is often the only survivor in land that has been greatly overmanured; hence its dominance in deserted barnyards and feedlots.

A number of striking and interesting ideas have been crystallized by plant sociologists out of the mother liquor of our common knowledge of plants. For example, everybody who has ever spoken about plants publicly or privately has tried to tell how much of each kind or of some one kind of plant there is on a given area. It is common or rare or abundant or scarce. It helps but little to count the plants and, besides, counting may be extremely laborious. A plot may have three oak trees and a thousand shoots of grass, but the three oaks far outdo the thousand grasses in controlling the situation. The forester will calculate the number of board feet of lumber of each kind on his plot. But that is significant only to the lumberman. For a mature pine will require only 15 square meters of space, while an oak will require much more. The plant sociologist considers first the amount of ground covered by each kind of plant. He imagines the entire plant projected on the ground, as if photographed from an airplane. A wooded hillside may have a 90 per cent. cover of chestnut-oak 60 feet tall, an 80 per cent. cover of laurel or rhododendron six feet tall, and a 90 per cent. cover of mosses on the ground. This statement tells much about the kind of woodland, and the effective quantity of each kind of plant. Thus the quantity of plants is best expressed by their coverage.

A further clearing of our thought is given by the ideas of constancy and fidelity, the extent to which a kind of plant is constantly found in certain kinds of vegetation, and the extent to which it is confined to a certain kind of plant society and is therefore characteristic of it. A plant of high constancy and fidelity becomes an indicator of the local conditions of soil and climate. It is in itself a summary report of the Weather Bureau and the Soil Survey. In southeastern Pennsylvania, the creeping phlox and the big white Cerastium are strictly confined to the societies of Serpentine rock. If you tell me you have wandered under the great coast redwoods of California, I can tell you not only what part of California you were in, but what shrubs and flowers and mosses you should have noticed also. The coast redwood is a "constant" of a certain social alliance. But other plants are almost wholly lacking in constancy. If you found a dandelion, I don't know anything about where you were. Dandelion is ubiquitous. We call it an ubiquist.

The concept of vitality is rarely appreciated without careful consideration. Where is a plant really at home? Where it flourishes and raises progeny, of course. By the test of reproduction, we find great numbers of plants that are away from home—strangers. The evergreens in your yard—do they yield any seedlings? The rhododendrons—do they even set seed? The dogwoods, redbuds, arbutus, harebells, Mimulus, wild poppy—are they just holding their own, or dwindling slowly? Are new plants or patches appearing in favorable seasons? Is it well with their vitality? If not, what of the future?

Aggressiveness is another concept of extreme interest. Wherever changes of vegetation are in progress, as on abandoned land or regenerating forest or in a garden or on a farm, what is the aggressiveness of the different plants and societies? Which groups force their way against all comers, and under what conditions? What is going on at the margin of a wood? Which plants are spreading and which retreating, and how and why?

Constructiveness and destructiveness

are equally important ideas. Recently published work of Dr. Blizzard at Cold Spring Harbor, New York, has shown that the shrubby bayberry is highly constructive in that it can grow on bare gravel and there build up a humus soil in which maples and oaks can and do start and grow into valuable trees. The same study shows that grapevines and Virginia creeper and Japanese honeysuckle are highly destructive. They clamber over the tall trees, and cut off the light from the tree leaves, and weight down the tops with an unbearable load of vegetation. The forest crumbles beneath the vines.

There is much that is not new in plant sociology; all outdoor folk know the general facts. Like many another science—medicine, mechanics, management—plant sociology gives dignity and precision to the knowledge gained by generations of observant practical men and women. It points the way to the finding of answers to the questions these men and women are asking. In this lies the guarantee of its progress and permanent value.

BAMBOO, THE UNIVERSAL PROVIDER

By Dr. WILLARD M. PORTERFIELD, Jr.

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WHEN the claim is made to the world at large that a certain tree is the most useful in the world, it is generally assumed that the person advancing such a claim has been careful first to study the merits of other useful plants. It is also true that a plant universally used in one small part of the globe may not be so used in other and larger regions. I am referring specifically to the claims put forward in an article published in the SCIENTIFIC MONTHLY for September, 1928, entitled "The Most Valuable Tree in the World." The coconut is the tree referred to. The article is pro-coconut exclusively, not one line of acknowledgment being allowed any other plant. In view of the broadcast appeal at the end of this article calling on all and sundry to furnish, if they can, evidence that any other tree "can offer the varied uses of the coconut," I am inclined to doubt whether the author ever considered bamboo.

There is a war in Shanghai and one does not know from day to day what is going to happen, but as college exercises have been suspended I have a little time in which to tell the world that besides the Far Eastern problem there is also bamboo. I can at best in the time and space available only skim the subject of bamboo, but I can at least indicate with a few concrete illustrations the far-reaching usefulness of this plant. Botanical descriptions can be had from technical works, so that I shall not spend time on that aspect. I shall deal only with the uses of bamboo in an endeavor to substantiate my claim that the humble bamboo may dare to rival the coconut as the "most valuable tree on the face of the earth."

To begin with, bamboo is a tree-grass. The culms, aside from their subterranean connections with the plant as a whole, are woody, branched and tall, some species reaching more than a hundred feet into the air. Every year they extend their total leaf surface, in spite of the fact that the culms individually show no increase in girth. Extension of leaf area is balanced by elongation of the rhizome and by the production of more culms. The point is, the aerial part of the bamboo is undoubtedly treelike and as such can be admitted to the category of trees comparable with the coconut. It now remains only to show that the bamboo is as useful.

In China the use of bamboo extends back into history so far that, when the present ideographs used in Chinese writing were developed, one of the elementary radicals which share in the formation of some of these characters was the one for bamboo, ⺮ which is in reality a picture of two culms standing side by side, bearing a branch and a leaf each. It is so linked with the life and customs of the Chinese people that without it the farmer in particular could not get along. In fact, it is said by the Chinese that without one useful plant like bamboo no country can thrive. Not only China, but also Japan, Formosa, the Philippine Islands, Siam, Indo-China, India, Ceylon, Sumatra, Java and the Malay Archipelago are all productive of bamboos, whose uses have been exploited since time immemorial. In other parts of the world the West Indies, Central and South America, Brazil in particular, to which may be added finally parts of Africa and Madagascar, have long

PHYLLOSTACHYS BAMBUSOIDES
SHOOTS COMING UP IN MAY, NEAR HANGCHOW, CHINA.

ago availed themselves of their native bamboos.

There are two ways of learning about an object. One is to observe it one's self, the other is to read about it. In my own experience while living in Shanghai I have seen bamboo used for almost every purpose. In my tours of inspection around the campus with the head gardener I have had many occasions to put my O. K. on requests for new bushel baskets, tool handles, carrying poles, basket trays for carrying pots of plants, new fences and fence-posts, ladders, poles to be split into stakes and made into frames for the support of flowers, and poles on which to hang back-nets for the tennis courts, all made of bamboo. Possibly at the time one of the coolies while mowing the lawn was wearing a sun hat made of fine strips of bamboo woven together, while his helper may have been wielding a bamboo stick to urge the donkey to haul the mower "more fast." As we pass an amah comes scuffling along with a big bamboo basket loaded with vegetables which she has just bought in the near-by village. Farther on some coolies who have been unloading coal sit down for a rest. One brings out his tobacco pipe for a brief whiff. It has a diminutive bowl and long bamboo stem. From a bamboo box made by sawing off one of the short sections from the lower end of a bamboo pole he extracts a pinch of tobacco and fills his pipe. The garage which houses the family Chevrolet, some details of which may be observed on the next page, is made of split bamboo, lined inside with plaster and thatched with rice straw. A tall apartment house just completed, which I pass on my way to town, is emerging for the first time to the light of day through the removal of its screen of split bamboo mats and bamboo scaffolding poles bound together with bamboo thongs. Along the road I pass a native restaurant and observe that the noon-day rice is being kept hot in small buckets made of bamboo slats held together by hoops of stripped bamboo. When I return to luncheon, among the vegetables on the menu are delicious creamed bamboo shoots sliced. From somewhere in the back quarters are wafted in to me the plaintive notes of the bamboo flute interspersed with occasional scrapings and squeaks of the Chinese violin, some of which are also made of bamboo.

GROVES OF CULTIVATED BAMBOOS
NEAR SHANGHAI, CHINA.

THE FAMILY GARAGE

DETAIL OF WALL CONSTRUCTION WITH WINDOW FRAME AND SHUTTER OF SPLIT BAMBOO.

In pleasant weather on almost any late afternoon in peaceful times may be seen the familiar figures of Chinese gentlemen listlessly plying a bamboo fan with one hand, while carrying a finely made bamboo cage in the other as they stroll about with their pet birds, the women folk in the more conservative families remaining behind doubtless to pass the time playing mahjong with prettily decorated ivory-faced bamboo tiles. High up in the air fantastic centipede kites constructed of bamboo splints zigzag back and forth or float lazily poised, while little sister watches near-by as she tends small baby brother who is ensconced in a sort of basket go-cart made principally out of woven strips of bamboo. Down by the canal a junk is unloading and the stevedores, as they come off with each bale, hand a bamboo tally to a clerk. At the same time an accountant at a table poises pen of bamboo over his ledger ready to enter the item required. As the work progresses I observe that some hands begin taking turns at pumping bilge water out of the junk and perceive that the pump is made of bamboo. Recently on a visit to the country I watched a well being dug in the alluvial silt which constitutes our land. A bamboo pole sharpened at one end with the partitions knocked out was used as a drill. This affixed to another pole was suspended from a horizontally placed bow made of several bamboo poles lashed together, the whole being 20 to 30 feet in length, which acted like a spring to draw up the drill between blows. In conclusion, I should like merely to mention the fact that in addition to those already indicated there are innumerable ornamental and what might be termed symbolical uses of both living and pictorial bamboo, of which at present there is no time to tell. This brief exposition based on actual experience, it seems to me, is sufficient to justify the name "universal provider" for bamboo. It suggests furthermore that a full study of the uses of bamboo in any region does in itself give one a very good idea of the character and customs of the people living there, so closely is it connected with their daily life.

Let us pass on now to comments about bamboo taken from the writings and experience of others. Supplementary evidence from the observations and experience of the explorers especially will contribute still more support to my

AN APARTMENT HOUSE
WITH ITS CLOAK OF MATS AND SCAFFOLD POLES AT SHANGHAI.

assertions with regard to the usefulness of bamboo. The historic travels of Marco Polo were among the first to reveal to the western world the domestic value of bamboo. He tells how the Chinese manufactured cables for towing ships by first splitting canes their whole length into thin pieces and then by twisting these together into ropes three hundred paces long. It is interesting to note in passing that engineers experimenting for the Whangpoo Conservancy Board found twisted and plaited ropes made with material taken from the outer eighth of an inch of bamboos about four inches in diameter being used to tow junks up against the current of the rapids in the gorges of the Yangtse River and estimated that the working stress was about 10,000 pounds per square inch of the material, this tension every now and then being doubled. Marco Polo also describes a novel method of protection used by travelers passing overland where there was danger of molestation by wild beasts. Several bamboo poles in a green state tied together, he says, were placed as evening approached at a certain distance from their quarters with a fire lighted around them. The action of the heat on the green wood was to generate considerable steam pressure in the hollow internodes, causing them to explode at intervals with a loud report which frightened away prowling beasts.

During his famous trips to the tea countries of China and India Robert Fortune had the opportunity of observing bamboo in its many aspects. He describes in detail the native method of

SPLIT BAMBOO BASKETS
IN A SHOP AT THE ANNUAL BAMBOO BAZAAR AT BUBBLING WELL, SHANGHAI

BUNDLES OF BAMBOO STRIPS
FOR BASKET WEAVING HANGING UP TO DRY NEAR HANGCHOW.

making paper in China. Bamboo was the source used, and the process while laborious was faithfully carried out. Apparently bamboo poles are soaked in water, then split and saturated with lime and water until they become soft. They are then beaten into a pulp by hand or by crude mechanical stampers, after which the mass is taken to a furnace and well boiled until it has been reduced to its finest elements. It is then formed into sheets of paper. Again he relates in interesting fashion the business of carrying poles down the mountains to the nearest waterway, where in the form of rafts they are floated down to the many markets that await them. In the spring the young shoots are also sought out and shipped. In conclusion, Fortune makes the following statement:

"Thus this valuable tree which is cultivated at scarcely any expense gives employment and food to the natives of these mountains (Ningpo to Kwaungtung) for nearly one half of the year."

There are some very unique uses to which bamboo has been put that might be of interest. E. H. Wilson, in "A Naturalist in Western China,"[1] describes the great bamboo cable bridge which spans the Min River on the road to Monkong Ting. It is 250 yards long and 9 feet wide, and is built with the exception of the floor planking entirely of bamboo cables. There are seven supports placed equidistant, the middle one being made of stone. The cables are twenty in number, ten supporting the floor and five on each side forming the "rails." The cables are made of split

[1] Vol. 1, p. 171.

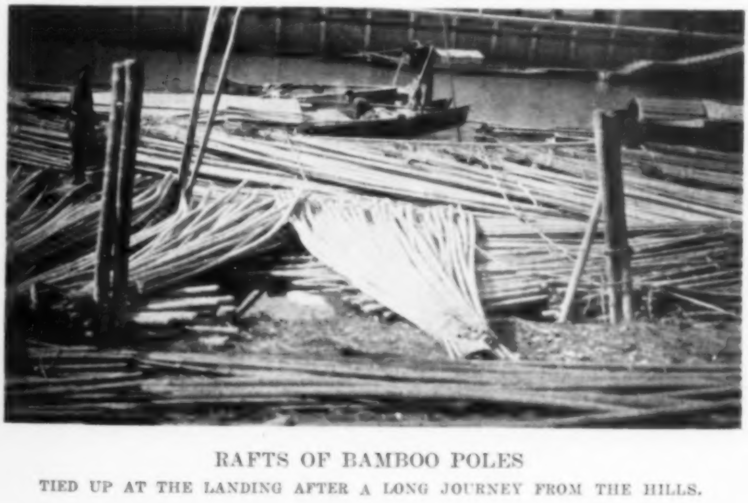
BAMBOO SHOP IN THE VILLAGE NEAR SHANGHAI.

and twisted bamboo culms, are 21 inches in circumference and are held taut by large capstans embedded in masonry. The bridge planking is held down with bamboo ropes and the cables are kept in place with lateral strands. Not a single nail or piece of iron is used. This is not the only bamboo bridge in China, and China furthermore is not the only country where bamboo bridges occur. Bamboo suspension bridges are also met with in Java. These, however, are not made with cables but with poles lashed together.

In the Philippine Islands there is an organ built entirely of bamboos, the only one of its kind in the world. It is in the Las Piñas church. The construction of this organ was begun in 1818 by Father Diego Cera and it is said 950 bamboo tubes of different sizes were used. The Shanghai Police Museum of Crime boasts of one exhibit certainly which demonstrates the skill of the Chinese in applying bamboo to use. It is a weighing machine made especially for crickets. Fighting crickets, like prize fighters, are accurately weighed and the machine by which it is done is made of bamboo and a delicate spring. Tabashir is always mentioned in connection with the uses of bamboo. It is an opalescent accumulation which is found inside the internodes of *Melocanna bambusoides*. The substance is chiefly silica and potash, and according to A. B. Freeman-Mitford, C. B., in his "Bamboo Garden" (1896), it is a famous medicine used for any and all ailments. E. W. Brandes on his expedition by seaplane into Papua[2] tells of a kind of xylophone made of tubes of bamboo. Photographs also appear with this article of natives wearing nose plugs of bamboo. David Fairchild arouses our respect for the Javanese carpenter in his account[3] of the expeditious way in which he can with a few deft strokes of a cleaver flatten out a bamboo culm into so many strips of flooring for the new house that is being built.

One of the most thorough investigations of the uses of bamboo is that carried out by Hans Spörry and published jointly in 1903 with Dr. C. Schröter, who wrote the botanical introduction. The study was undertaken in Japan and concerns the uses of bamboo in Japan only. Spörry lists 1,048 practical uses, which represents really an enumeration

[2] *National Geographic Magazine*, lvi, 3, 1927.
[3] "Exploring for Plants," p. 403, 1930.



RAFTS OF BAMBOO POLES
TIED UP AT THE LANDING AFTER A LONG JOURNEY FROM THE HILLS.

A BAMBOO CABLE BRIDGE

ACROSS THE MIN RIVER NEAR WENCHUAN NORTH FROM CHENGTU. Through the kindness of Dr. R. G. Agnew.

of Japanese articles of bamboo contained in his own collection. The remainder up to the total 1,546 includes also the ornamental uses. These uses with variations would stand almost as they are for China, too. The best accounts of the uses of bamboo in China can be had from the fifth edition revised of J. Dyer Ball's "Things Chinese."[4] The names of 83 uses are listed and these are in the form of general headings only, taking no account whatever of the many variations under each heading. The term "ornaments" alone, which is one of these, includes a great many articles. Again, Dr. S. W. Williams in the first volume of his "Middle Kingdom"[5] enumerates 82 uses of bamboo. Every part of the plant is used in some way. The shoots, roots, canes and leaves are all represented. The uses of the canes can roughly be classified under the form of the cane employed, *viz.*, canes, strips, splints, shavings. The leaves too serve as thatching material, lining for tea boxes, raincoats, large umbrellas, the larger leaves of forms like *Sasa tessellata* being used for wrapping sweets of certain kinds. In addition to those mentioned by Dr. Williams I would like to add that I have seen farmers around Hangchow wearing sandals made of the tough leathery sheathing leaf which covers the shoots of *Phyllostachys pubescens*. E. Hackel, in Natürlichen Pflanzenfamilien,[6] discusses the uses of bamboo generally. Among the 58 uses mentioned every kind of an article is included from Chinese junk masts to Burmese snuff boxes. We are surprised to learn that the production of great masses of seed, following one of those rare flowerings of the bamboo, while it may supply the countryside with a fair substitute for rice in case of a shortage at the time, is not an unalloyed blessing. On the contrary, it supports a tremendous increase in the rats and mice which, when the surplus of bamboo seed has been devoured, overflow into the neighboring fields and destroy the crops growing there. Such is the experience of the German colonies in the Brazilian prov-

[4] 1925, pp. 59–63.

[5] 1883, pp. 358–360.

[6] Engler and Prantl, II Teil, 2 Abteilung, pp. 89–97, 1887.

inces of Santa Catharina and Rio Gande do Sul about every thirteen years.

One can not live long in a country where bamboos grow and are used by the people without feeling that bamboo has contributed a great deal to the progress of that people and that the mastery of its uses marks a cultural stage in the development of their civilization. One becomes still more convinced of this fact after reading such accounts as that of David Fairchild of the bamboo civilization of Java.[7] Archeologists would indeed be justified in incorporating in their historical outlines for tropical and sub-tropical Asia a definite Bamboo Age comparable with that of Stone or Bronze. With a material which lends itself so readily to manipulation it is no wonder that native craftsmen soon found it a field for exploiting their genius. Because of its great tensile strength, its capacity for splitting straight, its hardness, its peculiar cross-section, the ease with which it can be grown, a combination of useful traits found together in no other plant, bamboo is one of those providential developments in nature which, like the horse, the cow, wheat and cotton, have been indirectly responsible for man's own evolution. A tree which occupies so little space comparatively and demands so little attention, which attains its height in from thirty to sixty days only, the rate during the most rapid period of growth reaching sometimes as much as 90 centimeters in 24 hours, which again is so flexible and straight grained yet mechanically so perfect as to give satisfaction under the stress of all kinds of service, whose arching plumes finally under all conditions are so pleasing to the eyes—such a tree can not with all due respect to the coconut justifiably be given any but the première place of honor among all useful plants.

[7] "Exploring for Plants," Chapters xxx and xxxi, 1930.

DR. HENRY NORRIS RUSSELL

RESEARCH PROFESSOR OF ASTRONOMY AND DIRECTOR OF THE OBSERVATORY AT PRINCETON UNIVERSITY, ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION.

THE PROGRESS OF SCIENCE

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AT ATLANTIC CITY

UNDER the presidency of Professor John J. Abel, the ninety-first meeting of the American Association, together with thirty-nine associated scientific societies, convened at Atlantic City in the interval between Christmas and New Year's Day. It is the first time that the association has met at a resort city since the Saratoga meeting of 1879. Approval of the choice was shown by the fact that some fifteen hundred papers were read and that perhaps three times that number of people attended the sessions.

The general impression made by the Atlantic City meeting was most favorable. In addition to exceptionally good and well-organized section and society programs there were numerous and diversified symposia, bringing out the present state of our knowledge on many subjects, and a most excellent exhibit, both scientific and commercial, supplementing the programs of papers and addresses. The popular lectures, too, were well selected and unusually interesting.

At the opening session, held in the ballroom of the Municipal Auditorium, Mr. A. H. Skean, the director of the Atlantic City Convention Bureau, welcomed the association to Atlantic City and Professor Luther Pfahler Eisenhart, dean of the faculty of Princeton University, to the State of New Jersey. Dr. Abel introduced the retiring president, Dr. Franz Boas, who addressed the meeting on "The Aims of Anthropological Research." On its conclusion a general reception was held in the Vernon Room of the Haddon Hall Hotel which was very well attended.

A feature of the program was the first Maiben lecture, given by Dr. Henry

THE BEACH AT ATLANTIC CITY

WITH THE BOARDWALK AND SOME OF THE HOTELS IN THE BACKGROUND.

—*Aero Service Corporation*

A PHOTOGRAPH OF ATLANTIC CITY FROM THE AIR

SHOWING THE MUNICIPAL AUDITORIUM, THE PIERS AND MANY OF THE HOTELS.

PROFESSOR JOHN J. ABEL

A PHOTOGRAPH OF THE PRESIDENT OF THE ASSOCIATION TAKEN AT ATLANTIC CITY.

Norris Russell, of Princeton University, the new president of the association, who spoke on "The Constitution of the Stars." The Maiben lectures were established in memory of the late Hector Maiben, of Lincoln, Nebraska. These lectures will deal authoritatively with topics of active scientific interest on which the speaker possesses the right to an opinion by virtue of his personal work. They will, however, be designed for a general audience rather than for specialists.

From a program so diversified and so generally excellent as that arranged by the section and society secretaries, and by the permanent secretary of the association, for the Atlantic City meeting, it is with great hesitation that one selects items for special mention. Yet attention should be called to the fact that two of the symposia proved especially popular.

One of these was the symposium on the timely topic of stabilization of employment, which was discussed by fourteen of our leading authorities on economics, and the other was the symposium on cosmic rays in which Dr. Robert A. Millikan, Dr. Arthur H. Compton and others presented the latest results of their work.

Responsibility for the conduct of the affairs of the association rests mainly upon the shoulders of the permanent secretary. At the Atlantic City meeting Professor Henry Baldwin Ward was chosen for this important position. Professor Ward has long been connected with the association; in 1901 he was secretary of Section F (Zoology), in 1903 he was general secretary, and he was a vice-president in 1905. For a number of years he has been in the closest pos-

DR. HENRY B. WARD

PROFESSOR OF ZOOLOGY, UNIVERSITY OF ILLINOIS, ELECTED PERMANENT SECRETARY OF THE ASSOCIATION.

sible touch with its affairs as a member of the Executive Committee of the Council.

Through our eyes we learn quite as much as through our ears. These two channels for acquiring information supplement each other, and through the joint use of both we lay a firm foundation for proper understanding. So in any well-balanced scientific meeting oral exposition of facts should, so far as possible, be supplemented by visual demonstrations.

The visual demonstrations supplementing the papers read at the Atlantic City meeting were provided by the science exhibition including no less than forty-seven units, many of these made up of several or even many different items.

Among the exhibits were artificially flattened human skulls from Venezuela, apparatus for the study of cosmic rays, living Surinam toads from Dutch Guiana, rare forms of matter, apparatus developed for the measurement of photosynthesis as a function of wave-length and intensity of light, ultra-violet patterns on the wings of butterflies, samples of fish flour, fish meal and fish oil, apparatus for rearing blow-fly larvae for surgical use, a recently discovered map of the prehistoric Indian earthworks at the junction of the Muskingum and Ohio rivers, and many other items of equal interest.

In addition to these exhibits there were shown laboratory equipment and supplies of all descriptions, and an attempt was for the first time made to bring together for inspection all the scientific books of the calendar year.

More extensive and more varied than in any previous year the exhibits at Atlantic City were one of the outstanding features of the meeting. But the programs of the sections and societies were unusually full and interesting.

AUSTIN H. CLARK

THE PRESIDENT OF THE AMERICAN ASSOCIATION

DR. HENRY NORRIS RUSSELL, research professor of astronomy and director of the observatory at Princeton University, was elected president of the American Association for the Advancement of Science at the Atlantic City meetings.

Russell first attained general recognition by his work in the field of stellar constitution and evolution about 1913. Starting from Hertzsprung's differentiations of red stars into giants and dwarfs, he organized the luminosity-type diagram—which shows relations between intrinsic brightness and the surface temperatures of stars. He gave physical interpretation to this now well-known picture by following lines suggested many years before by H. Laue and Sir Norman Lockyer. Subsequent developments in atomic physics, which could not have been foreseen, have invalidated Russell's theory, but the diagram itself has exercised controlling influence on the advance of stellar physics. He has continued contributing to this now very complex subject, and in the first Maiben lecture at the latest meeting of the American Association for the Advancement of Science he presented a critical summary of current knowledge. He gave an earlier summary in a course of Lowell lectures in 1931.

Early in 1923, as the direct result of arranging demonstrations of spectra for an undergraduate course, he became interested in the expanding subject of the relation of spectra to atomic constitution. In collaboration with F. A. Saunders he attributed the anomalous terms in the spectra of the alkaline earths to the joint action of two electrons, initiating the interpretation of complex spectra. He has taken an extensive part in the analysis of such spectra. Another series of papers deals with astrophysical applications of these principles and of ionization theory, culminating in a study

of the composition of the sun's atmosphere (1929) and in studies of stellar spectra made in collaboration with W. S. Adams and Miss Moore.

In positional and dynamic astronomy, mention may be made of his work on stellar parallax (published 1911); on the photographic determination of the moon's place; and on dynamical parallaxes of double stars—the latest list by Russell and Miss Moore includes 1,777 objects. Photometric interests are represented by a discussion of the albedo of the planets and satellites (1916) and a series of papers on the determination of the elements of eclipsing variables (partly in collaboration with Shapley, then a graduate student). His war-work on airplane navigation also may be mentioned. J. Q. S.

THERMODYNAMICS AND THE RELATIVITY THEORY

DELIVERING the Josiah Willard Gibbs lecture before the American Mathematical Society and the American Association at Atlantic City on December 29, Professor Richard C. Tolman extended thermodynamics to Einstein's special and general theories of relativity. According to an abstract prepared by *Science Service* he arrived at findings that promise to have profound influence on philosophy and even religion as well as on science.

Old-fashioned, classical science viewed the universe as running down in energy like a clock, eventually dying a "heat-death" when all heat and energy arrives at a dead level. Professor Tolman's greatly simplified cosmological models hold the hope that under the new relativistic thermodynamics the universe can forever and ever experience a succession of irreversible expansions and contractions.

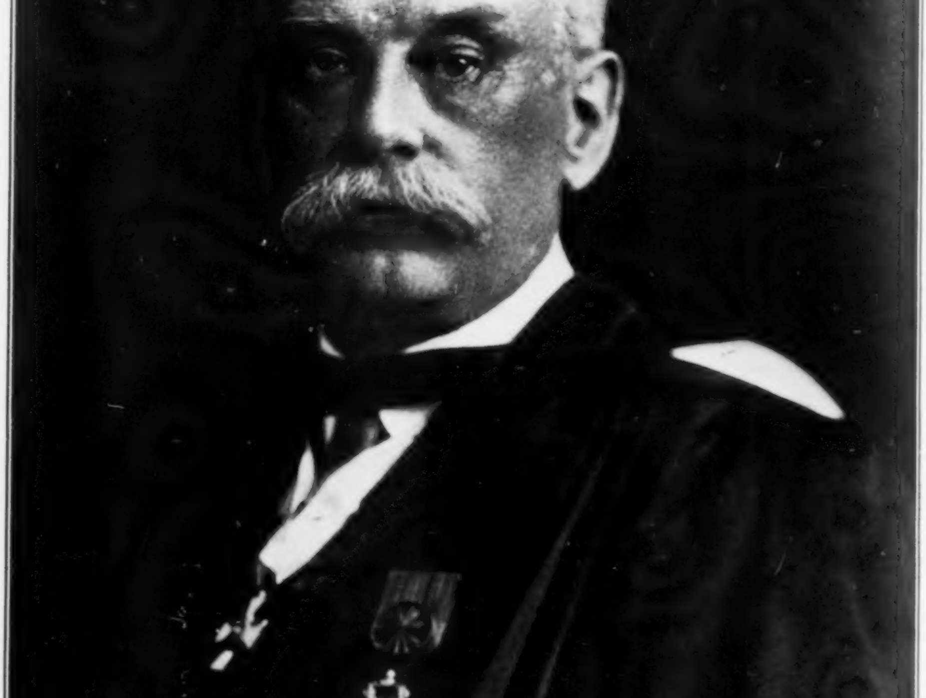
This fits in with the astronomical observations that we live in a rapidly expanding universe in which the great stellar galaxies are rushing away from us at speeds of thousands of miles a second. Professor Tolman's tentative idea of the universe explains how it is possible that it is now expanding, that it previously contracted, that it will contract in the future and that this cycle will continue unendingly.

A creation or beginning of the universe is necessary under our ordinary, every-day, classical ideas. Professor Tolman's marrying of thermodynamics with relativity may have removed the necessity of thinking of the universe having a beginning. In the "cautious position" to which he is taken by his mathematics and physics, "we no longer dogmatically assert that the principles of thermodynamics necessarily require a universe created at a finite time in the past."

Gibbs was the great American scientist who gave the classical principles of thermodynamics their most complete and comprehensive expression. Delivering a memorial lecture named in Gibbs's honor, Professor Tolman told why it has become necessary to extend the classical thermodynamical principles to relativity that has so greatly influenced all science in the last two decades.

Classical thermodynamics was developed with the assumption that the things about him were at rest with respect to the observer. Professor Tolman found it necessary to develop thermodynamics for observers in uniform relative motion to each other as is the case in the Einstein special theory of relativity.

The old-fashioned thermodynamics applied to space and time that had limited range and lacked strong gravitational fields. Professor Tolman found it necessary therefore to extend thermodynamics to Einstein's general relativity in order to consider the heat-energy behavior of large portions of the universe. The older ideas of heat and energy needed refining in just the same way that Einstein found it necessary to develop a theory of gravitation that is more precise than Newton's.



WILLIAM JACOB HOLLAND

THE DISTINGUISHED NATURALIST WHO DIED ON DECEMBER 13 AT THE AGE OF EIGHTY-FOUR YEARS.

REMINISCENCES OF A NATURALIST

EIGHT days before his death Dr. William J. Holland, for thirty-four years director and director emeritus of the Carnegie Museum, Pittsburgh, wrote the following letter to Mr. F. Dale Portiue, of Columbus, Ohio:

Your letter of December 4 has just been received. Some day or other, if life is spared to me, I hope to be able to write an autobiography, in which I certainly shall have occasion to tell many an amusing story about bugs, bones, and big-wigs. Your request to let you have a little chapter out of that autobiography, in order to include it in the paper which you tell me you intend to present, "stirs up my pure mind by way of remembrance."

You ask me the reason why I like nature-study. I will endeavor to be brief.

My love of nature is, I think, inherited. My mother's father was an amateur botanist of more than ordinary ability, the friend and correspondent of Shortt, Torrey, Mead, Darlington, Asa Gray, and a host of others. The herbarium he made is now deposited in the Carnegie Museum and is my property. It is large and rich in specimens labelled by the fathers of American botany. My father's father was a florist, and also an amateur botanist, in North Carolina. He built the first greenhouse erected in that State. My father was deeply interested in natural history from his boyhood. He went as a missionary to the West Indies, and there made a large collection of dried plants and of shells. On a furlough to the United States he took his plants to Bethlehem, Pennsylvania, to endeavor to have them determined, in part at least, by my mother's father. He there met my mother, they fell in love with each other, and were married. I am the child, therefore, of a botanical alliance. When my parents went back to the mission station in the West Indies they went on with their work of collecting. My father's house was the resort in Jamaica of visiting naturalists. Such men as P. H. Gosse, and C. B. Adams stayed for longer or shorter periods under the roof. C. B. Adams, who was the State Geologist of Massachusetts, and who with my father's help made a great collection of the shells of Jamaica, rocked my cradle. Of course I do not remember that fact, but I have been told so. Adams was professor at Amherst College, and it was because of my father's admiration for Adams that I long afterwards was sent to Amherst.

When my parents left the island of Jamaica, owing to my mother's ill health, my father became the pastor of a Moravian Church first at Dover and then at Sharon near Tuscarawas, Tuscarawas County, Ohio. My earliest recollections as a child are of being permitted, as a reward for good behavior, to look at the cabinet of shells, to carefully open and study the boxes of butterflies and beetles which my father had brought from the West Indies, and, a little later, I was set to work to collect land-shells and flowers about Tuscarawas in your own State of Ohio. My father taught me the scientific names of the plants and of the shells before I even knew their common English names. When I was a child of eight I knew that white clover was *Trifolium repens*, that the bluebird is *Sialis sialis*, etc. I can never forget my Ohio days. I can still see the nests of the red-winged blackbird among the wild roses in the swampy meadow before our house. I remember the meadow-lark which lured me from her nest in the grass by feigning to be crippled, and then flew away and gleefully chanted her delight. I can still see the toads spawning in the brook. Many strings of sunfish I caught in the Ohio Canal and many a channel-catfish (some of them big ones) I caught on my out-lines which I set just below the State Dam on the Tuscarawas River.

When the family removed in 1858 (I being a boy of ten) to western North Carolina, I kept up my collecting. I had there at my command a copy of Wilson's Ornithology with Bonaparte's Supplement in four volumes; I had the first edition of Say's Entomology; and some others of these old and now little consulted books. I dug into them *con amore*. I knew all the birds' nests within a mile and a half of the village of Salem, now Winston-Salem. I reared butterflies and moths from the larvæ by the hundreds; I collected everything that I could lay my hands upon, and, though all but the botanical specimens ultimately were destroyed, I made what was really, as I recall it, a very considerable collection of insects, many of them representing species which were not named and described until a later date by such men as Grote, Le Conte, and Horn. These collections were left behind in 1863 when I came north with my parents by an underground route full of adventure. I was sent to college first at Bethlehem, then Amherst. I kept up my botanical collecting, but the insects were not pursued until after I had become settled in the pastorate of a church in Pittsburgh. Then I reverted to my early entomological love and I did not pursue my studies in a desultory way, but I resolved to master the subject. The literature of entomology was not accessible in Pittsburgh in the late seventies and early

eighties, so I began to buy books and I have spent tens of thousands of dollars in acquiring practically all the literature relating to the lepidoptera in whatever language written. I employed men to collect for me, not only in the United States, but in many foreign countries. I was the first patron of the late William Doherty who collected for me in the Himalayas, in Siam, in the various islands of the Malay Archipelago, in New Guinea and the Philippines, and at the close of his life in Uganda, Eastern Africa. I collected, myself, everywhere I went, and made large collections in Japan, where I was the naturalist of the United States Eclipse Expedition in 1887; I have bought many classical collections, among them the great collection of William H. Edwards, upon which was founded his great work in three volumes upon the butterflies of North America; I bought the collection of Mr. Theodore L. Meed containing the lepidopteras collected by the Wheeler Expedition to the Rocky Mountains in connection with the survey for a trans-continental railway; I bought a score of larger or smaller European collections; my collections of African lepidoptera, which are particularly rich, were made for me by missionaries to tropical West Africa who received their training as students in the Theological Seminary in Pittsburgh, of which I am now the Senior Trustee.

But I am running away from your question. I believe it was Pope who said of himself: ''I lisped in numbers for the numbers came.'' He was a ''born poet,'' so I may say of myself that I am a ''born naturalist.'' I love not merely to investigate and study the details of an insect, but in its broader outlines I love the study of nature in all of her ever-varying aspects. I have devoted a great deal of time to reading along the lines of physics and especially astronomy. In fact just after my graduation at Amherst I was offered a position as instructor in chemistry and physics at Robert College in Constantinople, but my father dissuaded me from accepting the post, because he wished me to go on in this country with my professional studies. I am personally acquainted with most of the leading astronomers of the world. Professor Langley was a dear friend and associate of mine, both before and after the time when I became the head of the University of Pittsburgh, and I was an eyewitness of many of those experiments which he made to determine the laws governing flight. So you see I have lived all my life in contact with biologists, physicists, and astronomers, and it would be very queer, indeed, if I were not an enthusiast along the lines of nature-study. For twenty-five years I have been a student of palæontology. I had studied palæontology as a boy at Amherst. When Mr. Carnegie induced me to take charge of the development of the great Museum which bears his name, he urged me to lay stress upon palæontology and told me he stood ready to furnish all the needed funds. The result has been the discovery of a vast quantity of wonderful material in the fossil quarries of our western country and among them complete skeletons of a number of huge dinosaurs. At Mr. Carnegie's request and at his expense I had the fun of setting up replicas of the dinosaur *diplodocus* in many of the national museums of Europe, and elsewhere, on which occasions I had the pleasure of making the acquaintance not only of the scientific men of the countries, which I visited, but of their sovereigns. I have ''stood before kings'' and emperors, many of whom have in recent years lost their ''jobs,'' or in the case of the Czar have been murdered. I could tell you many interesting and amusing things about these people, but you have tempted me to write quite too long a letter. I came to be a nature-lover because two generations before me were nature-lovers and the disease, if you choose to so call it, was in my blood.

My motive in writing *The Butterfly Book*, *The Moth Book*, and *The Insect Guide* was to help the young people of this generation, and to keep them from having to toil, as I had to toil as a boy, to find out something about the names and classification of the insects, which I collected.

Now, I think I have said enough, and if there is anything in this screed which you can use in your address you are at liberty to do so.